NORTH CAROLINA

DEPARTMENT OF CONSERVATION AND DEVELOPMENT

R. BRUCE ETHERIDGE, DIRECTOR

DIVISION OF MINERAL RESOURCES

JASPER L. STUCKEY, STATE GEOLOGIST

BULLETIN NO. 50

The Vermiculite Deposits of North Carolina

BY

THOMAS G. MURDOCK AND CHARLES E. HUNTER

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PREPARED AND PUBLISHED IN COOPERATION WITH THE TENNESSEE VALLEY AUTHORITY

UNDER THE DIRECTION OF

JASPER L. STUCKEY, NORTH CAROLINA DEPARTMENT OF CONSERVATION AND DEVELOPMENT

AND

H. S. RANKIN, TENNESSEE VALLEY AUTHORITY

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RALEIGH

1946

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Raleigh, North Carolina
July 1, 1946

To His Excellency, Hon R. Gregg Cherry,
Governor of North Carolina.

Sir:

I have the honor to submit herewith, as Bulletin No. 50, a report entitled "Vermiculite Deposits of North Carolina," by Thomas G. Murdock and Charles E. Hunter.

Vermiculite, a non-metallic mineral of a varied industrial use, is produced in North Carolina on a small scale. It is hoped that the information presented herewith will prove helpful to vermiculite producers and perhaps lead to an increased production.

Respectfully submitted,

R. Bruce Etheridge,
Director.

PREFACE

Vermiculite has been known to occur in North Carolina for many years and there has been a small commercial production for the last decade. The present report is the first attempt to set forth the pertinent data relative to its geological occurrence and technology, based on detailed field examination and laboratory testing.

These investigations were conducted in cooperation with the Tennessee Valley Authority during the summer of 1941; however, the pressure of a more critical war program has caused the delay in publication. Due to the excellent qualities of vermiculite as an insulating material, its possible use in an enlarged building program makes the publication at this date quite opportune.

JASPER L. STUCKEY,
State Geologist.

THE VERMICULITE DEPOSITS OF NORTH CAROLINA

By

Thomas G. Murdock[1] and Charles E. Hunter[2]

ABSTRACT

Vermiculite is a group of hydrated silicate minerals, with a mica-like cleavage and a peculiar quality of exfoliation with intense heat, that has become of commercial importance in recent years because of its insulating properties after dehydration. It occurs associated with the dunite and pyroxenite formations from Clay County northeast to Avery County, but the principal production has been in the Ellijay area of Macon County and the Swannanoa area of Buncombe County. The mining has been principally from shallow open cuts or drifts along the vermiculite veins.

Most of the North Carolina vermiculite has been exfoliated in oil-fired shaft kilns near the mines at Swannanoa and Franklin. The processed vermiculite is used principally for loose house-fill insulation and aggregate for refractory brick and lightweight insulating concrete.

More than 30 vermiculite deposits and prospects are described in this report. Exfoliation tests on samples from these deposits indicate that 14 of these are promising for commercial use and nine might be beneficiated to meet commercial standards. Some of the samples tested were found to be slightly friable, but the material produced by the commercial plants is equivalent in quality to the vermiculites from the western States.

Due to the nature of its occurrence, vermiculite cannot be blocked out or reserves estimated with any degree of certainty; however, a detailed investigation of the occurrences in the State indicates that there might be a probable reserve amounting to 212,000 short tons and an additional possible reserve of 228,000 short tons—a total of 440,000. The exploitation of this tonnage, however, may necessitate some concessions by the market, a wider use, especially in the region near the deposits, and a change in general mining methods. Utilization of the vast deposits of olivine might lead to the recovery of low cost by-product vermiculite.

INTRODUCTION

The vermiculites of North Carolina are associated with peridotites and other basic magnesium rocks, which occur coexistent with the Blue Ridge Mountains, and deposits of apparently commercial grade are found in a number of localities between Clay County on the southwest and Avery County on the northeast. The chief development has been around Ellijay, Macon County, and near Swannanoa Buncombe County. Promising deposits are found, also, at a number of localities in Macon and Jackson Counties. Many of the old abandoned corundum mines in Transylvania, Madison, Mitchell, Yancey, and Iredell Counties have showings of vermiculite. Plate 1 shows the location of the principal deposits which are described in some detail by counties in this report.

The commercial value of vermiculite prior to 1925 was of little or no importance, and the development and use of the mineral since that time has been due chiefly to the efforts of the Zonolite Company, whose mines are located at Libby, Montana.

Recognition of the value of vermiculite as an insulating material and as an aggregate in refractories and light-weight concrete has led to the development of an industry in North Carolina and since 1933 activities have been reported by several companies and individuals.[3] Exfoliation plants have been operated at Bee Tree, Bun-

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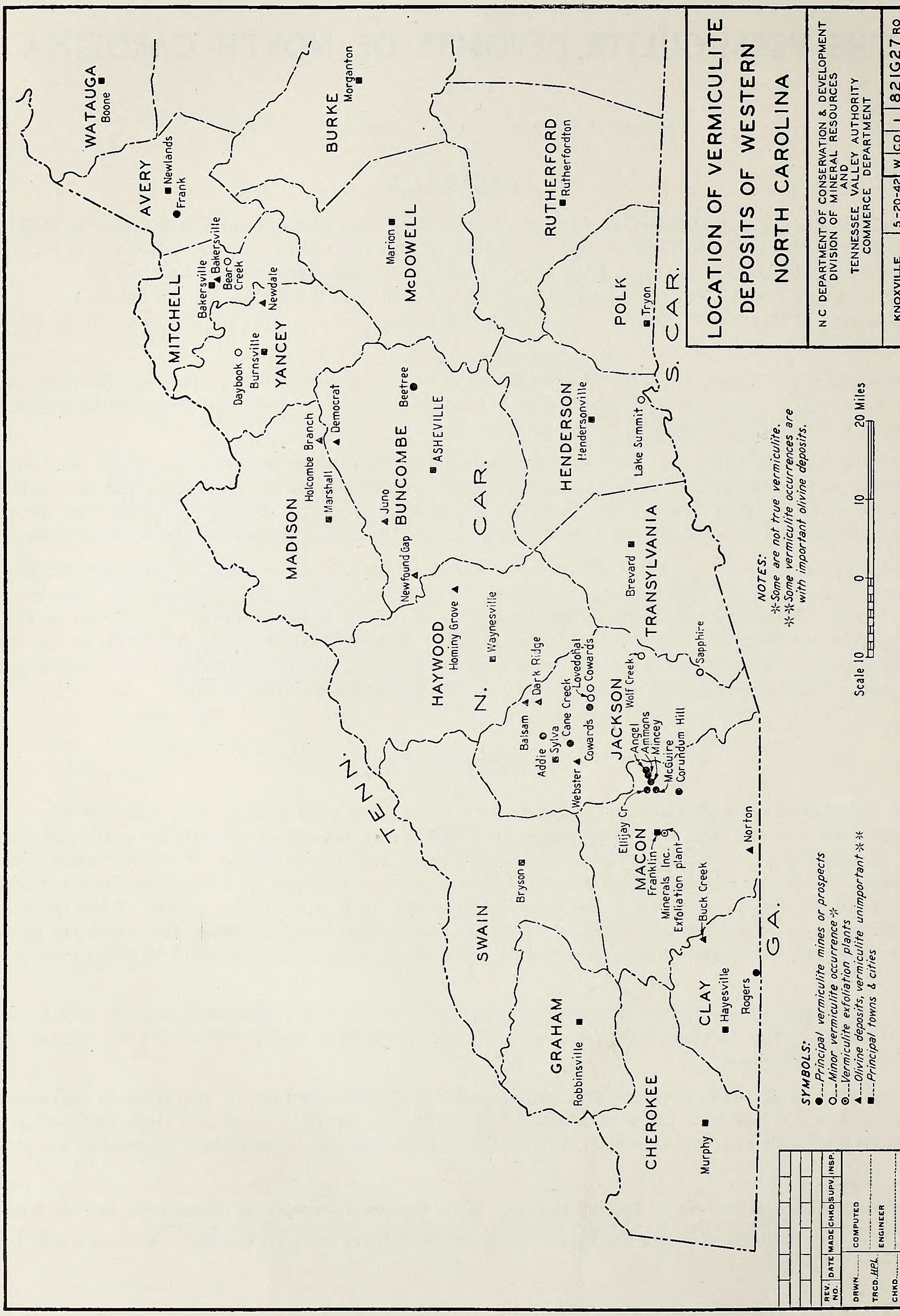
[1] Assistant State Geologist, Division of Mineral Resources, North Carolina Department of Conservation and Development.

[2] Geologist, Regional Products Research Division, Commerce Department, Tennessee Valley Authority.

[3] Hunter, C. E., and Mattocks, P. W., Vermiculites of western North Carolina and north Georgia: Tennessee Valley Auth. Geol. Bull. 5, p. 1, 1936.


LOCATION OF VERMICULITE
DEPOSITS OF WESTERN
NORTH CAROLINA
N C DEPARTMENT OF CONSERVATION & DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT
KNOXVILLE 5-20-42 W CO I 821G27 RO
NOTES:
*Some are not true vermiculite.
**Some vermiculite occurrences are
with important olivine deposits.
Scale 10 0 10 20 Miles
SYMBOLS:
●...Principal vermiculite mines or prospects
○...Minor vermiculite occurrence*
⊙...Vermiculite exfoliation plants
▲...Olivine deposits, vermiculite unimportant**
■...Principal towns & cities
REV. NO. DATE MADE CHKD SUPV. INSP.
DRWN. COMPUTED
TRCD. HPL ENGINEER
CHKD.
TENN.
N. CAR.
S. CAR.
GA.
WATAUGA
Boone
AVERY
Newlands
Frank
MITCHELL
Bakersville
Bakersville
Bear Creek
YANCEY
Burnsville
Daybook
Newdale
BURKE
Morganton
McDOWELL
Marion
RUTHERFORD
Rutherfordton
POLK
Tryon
MADISON
Marshall
Holcombe Branch
Democrat
BUNCOMBE
ASHEVILLE
Beetree
Juno
Newfound Gap
HENDERSON
Hendersonville
Lake Summit
TRANSYLVANIA
Brevard
Sapphire
HAYWOOD
Hominy Grove
Waynesville
JACKSON
Balsam
Addie
Sylva
Dark Ridge
Cane Creek
Lovedoftal
Cowards
Webster
Wolf Creek
Angel
Ammons
Mincey
McGuire
Corundum Hill
SWAIN
Bryson
MACON
Franklin
Ellijay Cr
Minerals Inc. Exfoliation plant
Norton
Buck Creek
GRAHAM
Robbinsville
CLAY
Hayesville
Rogers
CHEROKEE
Murphy

combe County, by Bee Tree Vermiculite Mines, Inc., and at Franklin, Macon County, by Minerals, Inc., and its successor, Vercalite Industries, Inc. Shipments of crude vermiculite have been made by R. G. LeTourneau Company of Toccoa, Georgia; Cary Minerals Company of Ellijay, Macon County; Philip S. Hoyt of Franklin, Macon County; and others.

This report presents data obtained in an economic geological field survey and laboratory investigations. The work was done during the summer of 1941 as a cooperative project of the Mineral Resources Division, North Carolina Department of Conservation and Development and the Regional Products Research Division, Commerce Department, Tennessee Valley Authority, under the direction of Dr. Jasper L. Stuckey, State Geologist, and Mr. H. S. Rankin, Senior Mining Engineer, respectively. The field investigations were in charge of Thomas G. Murdock, Assistant State Geologist of North Carolina, and Charles E. Hunter, Geologist, Tennessee Valley Authority. The exfoliation tests were made by Mr. F. A. W. Davis, Assistant Mining Engineer at the Authority's Minerals Testing Laboratory, Norris, Tennessee. Dr. W. A. Reid, Chemist, Division of Mineral Resources, furnished the vermiculite analyses except where otherwise mentioned. The authors were assisted in the field surveys by Messrs Mason K. Banks, John W. Harrington, R. S. Ingle, Roy L. Ingram, and William T. McDaniel, Jr., student aides from the University of North Carolina, State College and Chapel Hill units.

The field work was greatly facilitated by the helpful cooperation of many residents of western North Carolina, particularly that of Messrs. H. A. Coggins, George Coggins, and Eldredge Coggins of Bee Tree Vermiculite Mines; F. C. Cary and Alexander Ammons of Cary Mineral Company; E. C. Soper, Theodore Higdon, and Eldon Coggins of Minerals, Inc.; and Philip S. Hoyt of Southern Mining and Milling Company, Franklin.

PRODUCTION AND RESERVES

The following tabulation gives the production statistics for the entire United States, and for North Carolina during recent years when there were as many as three producers and the figures could thus be reported separately:

SCREENED AND CLEANED VERMICULATE SOLD OR USED BY PRODUCERS[4]

	UNITED STATES			NORTH CAROLINA		
Year	Short tons	Value	Value per ton	Short tons	Value	Value per ton
Average 1926-1930	604	$ 16,270	$ 26.94			
Average 1931-1935	3,352	41,822	12.48			
1936	16,933	185,787	10.97			
1937	26,556	260,664	9.77			
1938	20,700	192,000	9.28			
1939	21,174	174,587	8.25	1,400	$ 14,400	$ 10.29
1940	22,299	137,698	6.18	1,040	8,070	7.76
1941	23,438	125,444	5,35			
1942	57,848	319,931	5.53	1,612	19,048	11.75
1943	46,645	471,595	10.11			
1944	54,116	541,744	10.01			

[4] U. S. Bur. Mines, Mineral Yearbook, 1940 to 1944.

During 1943 the exfoliated material was quoted at 70 cents to $1.25 a bag, each bag containing 4 cubic feet and weighing 25 pounds, or $56 to $100 a short ton, f. o. b. works. Assuming an average value of $75 a ton for exfoliated vermiculite, and a 10 percent loss in weight on exfoliating, the value of sales in the United States, in 1944, would be approximately $3,652,800.

The nature of the occurrence of vermiculite in North Carolina does not permit blocking out ore. This is because of its irregularity and the undeterminable amount of gangue. Its continuity, both horizontally and vertically, is quite unpredictable. It is with considerable hesitation, therefore, that reserves are estimated. Nevertheless, the information gained from a detailed study of the active mining operations and knowledge of the general characteristics of the mineral give some data which may be applied in estimating unexploited deposits and unprospected areas. In a few cases it is possible to actually make a rough cubication (making a few assumptions as to unexposed dimensions), but generally the most practical method is to base the estimate on the reported production of some other property which offers certain general similarities. In considering the reserves on a regional basis, it is believed that the figures are conservative.

It seems desirable to make a separation of the reserves into two classes, on the basis of what might be termed "probable vermiculite" and "possible vermiculite." Any other classification is obviously impractical. These terms are purely arbitrary ones and indicate in general a different degree of potentiality.

No estimate can be attempted regarding the relative quality of the reserves. The exfoliation tests indicate that the samples from outcrops do not give an exact index as to the grade of the material which may be found at depth; the samples from producing properties are consistently heavier after exfoliation than is similar material when processed in a plant, due to the difficulty of reproducing commercial plant conditions in a laboratory. In general, it is believed that the estimated tonnages are of a quality which has some commercial possibility.

ESTIMATED RESERVES OF VERMICULITE IN NORTH CAROLINA

COUNTY	*PROBABLE* (*Short Tons*)	*POSSIBLE* (*Short Tons*	*TOTAL* (*Short Tons*)
Avery	14,000	9,000	23,000
Buncombe	45,000	34,000	79,000
Clay	10,000	10,000	20,000
Jackson	48,000	52,000	100,000
Macon	85,000	93,000	178,000
Others	......	40,000	40,000
Total	202,000	238, 000	440,000

PROPERTIES OF VERMICULITE

The properties of vermiculite have been summarized by Petar[5] as follows:

> The most pronounced characteristic of vermiculite is its extraordinary expansion on heating; the volume may increase up to 16 times the original (pl. 2). Some varieties contain as much as 20 percent of water and the expansion or exfoliation takes place in only one direction, at right angles to the cleavage. At the same time the color changes from black or dark brown to a silvery or golden hue, according to the degree of heat and the exposure to the air. The change of color is believed to be due to the oxidation of the iron. The specific gravity of the raw material is in the neighborhood of 2.5 whereas after heating, the expanded mass has been reported to have an apparent gravity as low as 0.087. The untreated material weighs about 100 pounds per cubic foot; after heat-treatment the average product varies in weight from 6 to 20 pounds per cubic foot.

The exfoliation of vermiculite has been described by Byers[6] as follows:

> The scales or plates of all micas and vermiculites have a strong tendency to warp when heated strongly and it is this warping that causes the expansion of the material. The dehydration causes unequal strain within the crystals when the water is expelled, and this strain causes them to warp and twist. The reason vermiculite expands is because the bonding of the planes of cleavage is weaker than the warping and twisting force and the plates are pressed apart, while in micas the bonds between the planes of cleavage are stronger than the twisting force which results in the same warping and twisting of the whole sheet, with some spreading thereof or a trace of swelling, but with no such expansion as occurs on heating a vermiculite in which the crystals are less tightly bound due to the natural solvent action along cleavages before the subsequent heat treatment. Warping occurs only while the water is being driven off and a dehydrated vermiculite will not warp or expand further with subsequent heating.

[5] Petar, Alice V., Vermiculite: U. S. Bur. Mines Inf. Circ. 6720, p. 1, 1933.
[6] Byers, W. B., Method of treating vermiculites, U. S. Patent 2,030,239, pp. 2-3, Feb. 11, 1936.

A. Lump of Crude Vermiculite.
B. Exfoliated Vemmiculite House Fill Insulation.

The thermal conductivity[7] of expanded vermiculite compares favorably with other materials, as shown in the following table:

THERMAL CONDUCTIVITY OF VERMICULITE COMPARED WITH OTHER MATERIALS[8]

Material	*Weight per cubic foot*	*Thermal Conductivtiy*[7]
Expanded Vermiculite	6 lbs.	0.26
Mineral Wool	2 to 7 lbs.	0.27–0.30
Compressed Cotton	6.3 lbs.	0.21–0.29
Pure Wool	6.24 lbs.	0.26–0.32
Cork, ground	8.1 lbs.	0.27–0.31

USES OF VERMICULITE[9]

The best grades of expanded vermiculite have a weight of 6 to 8 pounds per cubic foot. This low density, together with the properties of comparatively high refractoriness, low thermal conductivity, and freedom from deterioration, makes it ideal for thermal and acoustic insulation. Fireproof insulating boards made of the expanded material can be used between two sheets of metal in the form of standard units for pre-fabricated metal houses, and will withstand exposures to 1,700°F. without any appreciable expansion or contraction.

FIG. 1. PLACING VERMICULITE INSULATION IN ATTIC.

In loose, granular form, the expanded material is used extensively as a fill insulation in the walls and roofs of dwellings (see fig. 1), industrial buildings, furnaces, oven and refrigerators. It is also used in thermal jugs, as filling in life preservers, and as a loose fill for packing chemicals, shells and bombs.

Expended vermiculite, combined with bonding materials, is fabricated into a wide variety of products, such as pipe covering, insulating blocks, refractory insulating concrete, roof fill, high temperature cements, insulating and acoustical plasters and tiles, and structural roof slabs.

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[7] Conductivity: British Thermal Units transmitted per hour per square foot of material one inch thick, per °F. difference in temperature of the two faces.

[8] Tyler, P. M., Home insulation, an effective conservation and national defense measure: U. S. Bur. Mines Inf. Circ. 7166, p. 10, 1941.

[9] Gwinn, G. R., Marketing vermiculite: Bur. Mines Inf. Circ. 7270, pp. 9-10, January 1944.

Precast slabs of concrete, using vermiculite as an aggregate can be assembled into a finished structure, and can be sawn, cut, drilled and nailed in much the same way as lumber. Vermiculite concrete is an extremely light-weight building material, weighing 20 to 40 pounds per cubic foot. It has a compressive strength of 50 to 250 pounds per square inch and a thermal conductivity of 0.60 to 0.80 B.t.u. at 50° to 90° F. It is made like ordinary concrete; expanded vermiculite of 3- to 20-mesh size is used as an aggregate in place of sand, gravel, or stone. The most common use of vermiculite concrete is as insulating roof fill, lightweight soundproofing, insulating floor fill, and structural roof deck. Cants, saddles, and slopes for roof drainage also may be made from this. When poured around steel girders, vermiculite concrete protects them from buckling if they are exposed to prolonged intense heat, and, because of its light weight, it greatly reduces the dead weight in building construction. During the war, slabs and blocks of this concrete were placed on decks and used as fire walls on tankers in danger of bomber attack.

There is an increased use of vermiculite insulating brick. Industry utilizes a lightweight type made expressedly to obtain the lowest possible conductivity, even though structural strength is sacrifled, and also one which may be used for building purposes. The lightweight brick are used principally in the arches of open-hearth furnaces, where no structural strength is needed and where they may be used repeatedly. The structural brick find a wide utilization in petroleum cracking units, where they serve as a combination refractory and insulator.

A plastic insulation made with vermiculite is used on the exterior of boilers and refinery columns for heat insulation and on the interior of automobiles and airplanes for sound proofing.

Some highly specialized uses of vermiculite have been widely adopted by the trade; others are still in the experimental stage but may be expected to increase its future application. Some of the more common uses are as a filler for linoleum, an ingredient of grease and enamel, paint pigments, filter for greases and oils, partial substitute for cork, soil conditioner, and insecticide carrier.

The consumption of vermiculite in North Carolina, and the South in general, is expected to increase. This is an exceptionally good area for the marketing of insulation material, because of the extended hot season, the high cost of fuel during the winter, and the fact that the local supply of lightweight concrete aggregates is limited.[10] For several years vermiculite has been recognized as a satisfactory loose house-fill material in this area. Recently it has begun to be accepted as standard roof deck material for large flat top construction. Research is continuing on its use in plaster, acoustical board, light-weight precast concrete, pipe insulation, and protection for steel frame work, and the germination of seeds. According to laboratory tests conducted by North Carolina University[11] in cooperation with the Tennessee Valley Authority, vermiculites mined in North Carolina are equivalent in quality and interchangeable in use with the Montana vermiculites.[12]

GEOLOGY

Vermiculite, one of the important accessory minerals found in the peridotite formations of western North Carolina, was known in Massachusetts as early as 1824 when Webb[13] gave it this name from the Latin "*vermiculari,* to breed worms," because of its property of expanding and unfolding into worm-like forms when heated. Vermiculite is commonly regarded as an alteration product of biotite or phlogopite due to hydrothermal agencies.[14] Field evidence indicates that the North Carolina vermiculites more properly belong to the chlorite group and have retained the optical character and the cleavage of the original chlorite mineral from which they

[10] Moyer, F. T., Lightweight aggregates for concrete: U. S. Bur. Mines Inf. Circ. 7195, p. 24, January 1942.
[11] Scholes, W. A., and others, The development of lightweight concrete from North Carolina vermiculites: North Carolina Univ. Eng. Exper. Sta. Bull. 24, 70 pp., 1942.
[12] Bowles, O., Vermiculite: U. S. Bur. Mines Mineral Trade Notes, vol. 13, no. 6, p. 26, December 20, 1941.
[13] Webb, T. H., New localities of tourmaline and talc: Am. Jour. Sci., vol. 7, p. 55, 1824.
[14] Spence, H. S., Mica (Chapter), Industrial minerals and rocks (Seeley W. Mudd Series), Am. Inst. Min. Eng., p. 460, 1937.
Gwin, G. R., op. cit., p. 2.
Scholes, W. A. and others, op. cit., p. 7.
Kriegel, W. W., Summary of occurrencs, properties, and uses of vermiculite at Libby, Montana: Am. Ceramic Soc. Bull., vol. 19, no. 3, pp. 94-97, March 1940.

were derived. It is believed that most of the North Carolina deposits have been formed by hydration and alteration of chlorite and that the type of chlorite altered frequently has determined the properties of the resulting vermiculite.

The rock formations in the mountain province of western North Carolina are mostly crystalline schists, gneisses and granites, and are considered to be pre-Cambrian in age. These formations have a prevailing northeast and southwest strike and a southeast dip, although locally these may vary considerably. The principal vermiculite deposits of the State are associated with dunites and pyroxenites intruded into these highly crystalline formations. These basic intrusions range in diameter from a few feet to more than a mile. The geological features of these dunite and pyroxenite formations were discussed in detail by Pratt and Lewis[15] and later by Hunter[16].

FIG. 2. OCCURRENCE OF SMALL PEGMATITE WITH VERMICULITE.

Vermiculite was first noted in North Carolina by Dr. Genth[17] in 1873 as a mineral associated with corundum. Essentiallly all the commercial production from North Carolina has been derived from deposits associated with ultra-basic igneous formations—dunites and pyroxenites. Vermiculite-like material of inferior quality is occasionally found associated with biotite schists and pegmatites. Some vermiculite probably occurs with all the basic-magnesian rock formations of North Carolina. However, the principal deposits are associated with the purest dunites and pyroxenites into which pegmatites have been intruded or segregated from the original basic magma (see fig. 2).

[15] Pratt, J. H., and Lewis, J. V., Corundum and peridotites of western North Carolina: North Carolina Geol. and Econ. Survey, vol. 1, 464 pp., 1905.
[16] Hunter, C. E., Forsterite olivine deposits of North Carolina and Georgia: North Carolina Dept. Cons. and Devel. Bull. 41, 117 pp., 1941.
[17] Genth, F. A., Corundum, its alteration and associated minerals: Am. Phil. Soc., vol. 13, p. 359, 1873.

The largest and most persistent of the vermiculite veins and lenses are found along the contact between the dunite or pyroxenite masses and the enclosing schists or gneisses. However, the purest veins are those along interior fractures or zones of weakness within the basic formation. The width of the vermiculite veins may vary from a tiny stringer to more than 20 feet. They usually have a steep dip and may strike in any direction. Small amounts of unaltered chlorite often are found in the vermiculite veins. The depth at which a vein is predominantly chlorite is generally determined by the depth of local weathering and drainage. It is interesting to note that core drilling of the dunite formation[18] at Webster has revealed vermiculite zones at a depth of 157 feet.

MINERALOGY OF VERMICULITE

The term "vermiculites" includes a number of individual minerals, members of a group of hydrated silicates, the best known of which are vermiculite and jefferisite. Dana[19] lists a number of other varieties including culsageeite, kerrite, lucasite, lennilite, hallite, painterite, pelhamite, philadelphite, vaalite, proto-vermiculite, maconite, dudleyite, pyrosclerite, roseite, and wilcoxite.

Pratt and Lewis[20] list six varieties from North Carolina and describe them as follows:

1. Jefferisite (or Culsageeite) occurs at the Corundum Hill mine in foliated masses of yellowish-brown color and also in greenish, brownish yellow scales not over one-eighth of an inch in diameter.
2. Kerrite consists of innumerable fine scales of a pale greenish-yellow color and of a pearly luster and was also found at the Corundum Hill mine.
3. Maconite was also found at the Corundum Hill mine and is a dark-brown scaly mineral with pearly luster inclining to sub-metallic. It closely resembles the scaly jefferisite.
4. Lucasite, also similar to jefferisite and found at the Corundum Hill mine, is yellowish brown in color and made up of small laminae not over 2 mm. in diameter. The basal cleavage is eminent and the luster is sub-metallic to greasy. It is found with grass-green actinolite.
5. Wilcoxite occurs in greenish white scales of a pearly luster, somewhat resembling talc. It has been identified at Shooting Creek and the Buck Creek mine in Clay County; also at the Corrundum Hill mine. It is one of the easier of the vermiculites to identify in the field.
6. Dudleyite has been found very sparingly. It has a soft bronze or brownish yellow color and a pearly luster.

All of these minerals have a decidedly soft greasy feel whether wet or dry and the laminae are elastic.

The following tabulation shows the varying chemical composition of the six varieties just listed:[21]

CHEMICAL COMPOSITION OF SOME NORTH CAROLINA VERMICULITES

	1a	2	3	4	5a	6
SiO_2	33.97	38.31	34.22	39.81	29.23	32.43
Al_2O_3	18.87	11.41	21.53	12.99	37.53	28.42
Fe_2O_3	5.17	1.93	12.41	5.29	1.33	4.99
FeO	0.46	0.32	0.32	0.11	2.41	1.72
NiO	0.46		0.12			
MgO	22.57	26.30	14.46	24.83	17.27	16.87
(NiCo)O		0.29				
Na_2O			0.51	0.20	6.49	1.52
K_2O			5.70	5.76	2.44	0.56
Cr_2O_3				0.54		
MnO				0.05		
CaO				0.14		
LiO_2						0.19
H_2O			11.85	10.76	3.66	
Ignition	18.83	21.22				13.43
Total	100.33	99.78	101.12	100.48	100.36	100.12
Specific Gravity		2.303	2.827			

a Average of samples from two localities.

[18] Hunter, C. E., Murdock, T. G., and MacCarthy, G. R., Chromite deposits of North Carolina: North Carolina Dept. Cons. and Devel. Bull. 42, p. 32, 1942.
[19] Dana, J. D., The system of mineralogy, descriptive mineralogy, 6th ed., pp. 664-668, New York, Jno. Wiley & Sons, 1909.
[20] Pratt, J. H., and Lewis, J. V., op. cit., pp. 319-322.
[21] Idem.

SAMPLING OF VERMICULITE DEPOSITS

In the course of the investigation 30 samples of vermiculite were collected. An effort was made to secure samples representative of the material which might be obtained by selective mining. Where stock-piles or materials in bins were available, at the active and abandoned properties, the sample was taken from these sources rather than from material in place. It is logical to believe that where the outcrops have not been prospected the vermiculite is very badly weathered and a sample taken at a greater depth would be higher grade. This fact should be considered in evaluating the results of the exfoliation tests.

The samples ranged in weight from 20 to 25 pounds when originally taken but were partly dried when they reached the laboratory. A 1-pound sample was taken from each larger sample for chemical analysis. The source of the sample is given in the Appendix following the description of the tests. Inasmuch as a satisfactory grade of vermiculite was being produced at the active properties, only a single sample was taken at some of these and more sampling was done at virgin deposits where there appeared to be sufficient quantity to warrant exploration. For purposes of comparison, several samples of material which was clearly not a true vermiculite were taken.

The samples were sent to the Authority's Minerals Testing Laboratory at Norris, Tennessee for exfoliation. The results of these tests are given in the Appendix of this report.

MINING METHODS[22]

Vermiculite along the contact zones of the dunite masses was a serious deterent to early corundum operations. The mineral is so soft and slippery that a tremendous amount of timber was necessary to hold the vermiculite in place so that the drift could be continued through the vein. In many cases the drift had to be abandoned because of the inability to hold back the vermiculite.

Many of these old corundum drifts have now been reopened to mine the vermiculite. In other localities, where vermiculite was found outcropping, new drifts were run to intersect the vein. If a large pocket was struck in these, a good tonnage could be recovered, but if the pocket proved to be small the venture often failed. One of the chief disadvantages of this method is the poor recovery in case all of the mineral does not slump, which is frequently the case since the veins alternately widen, pinch, and at times disappear completely. This method is also dangerous because the miners have to work under tons of material which they are trying to make fall. The frequent joints in the peridotite cause large blocks to become loose when undermined, and supporting these requires considerable timber. In some cases vermiculite caves all the way to the surface, causing subsidence and making impossible the recovery of any pockets which are not interconnected with that being pulled.

The principal underground development for vermiculite has been at the Ammons mine where over 1,100 feet of development work has been done. This includes a 96-foot shaft with drifts at the bottom and on an intermediate level. Other work consists of a series of drifts into the side of a hill, following interior zones of weakness in the weathered and serpentinized dunite. These drifts follow and intersect veins and zones of high-grade vermiculite, and are carried on a slight up-grade to provide drainage; they are irregularly spaced vertically and in general run in a northerly direction. The drifts are usually 6 feet high by 5 feet wide and had to be timbered and lagged as advanced. Local pine and chestnut timber was used, the size varying with the ground conditions. Drifting usually entailed only excavation of the ground by alternate picking and shovelling in the face; the weathered and serpentinized dunite is so soft that blasting is generally not necessary. Underground transport was by wheelbarrows equipped with rubber tires. The waste material was dumped near the mouth of the drift and the vermiculite into a wooden chute leading to a tram car on the level of the lowest drift, which carried it to the screening plant about 400 feet away. The gangue minerals were hand picked from the vermiculite as it came from the vein and the crude product was sometimes partially dried in the sun prior to screening.

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[22] Murdock, T. G., Vermiculite mining in North Carolina: Am. Inst. Min. Eng., Contr. 26-H, February 1942.

The Angel mine, adjacent to the Ammons, has been developed partly by drifts but more recently an open-cut method has been introduced, and also used at the Bud Mincey mine, just east of Ellijay Post Office. In this open-cut method a vein was located by the vermiculite float which occurs in the soil as flakes. The strike of the vein was determined as well as the location of any lenses near the surface. This can be done by a little pick work. Where outcrops are found to be large enough to mine, actual extraction can be started, either bagging the vermiculite immediately or drying it in the sun. When a pocket pinches out, or an excess amount of gangue or wall rock must be handled, the miners move along the strike to another location. As the cut gets deeper, a hand windlass mounted on skids is placed over the section being mined (see fig. 3) and the vermiculite is hoisted to the surface. At both these properties the wall rock is a fairly sound olivine and a few stulls are all the timber that is needed.

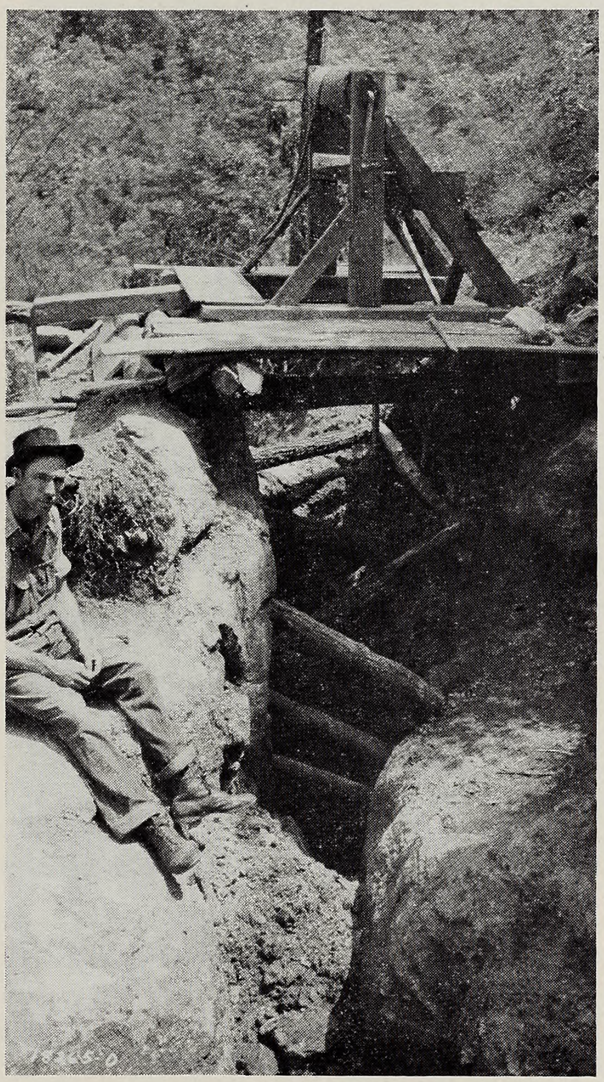


Fig. 3. Open Cut and Hand Windlass, Mincey Mine, Ellijay.

Operations at the Bee Tree mine were by open-cut methods, employing hand mining. The main production was from No. 1 pit (see fig. 4.) Overburden is absent on the northwest side but measures 4 feet on the southeast side. The pit reaches a maximum depth of 50 feet from the northwest rim where a joint surface of pyroxenite outcrops, forming the upper limit of the pit and dipping 54°SW. A road enters 6 feet above the bottom of the pit and permits proper spotting of a truck for transporting vermiculite to the plant and providing a bench for shovelling muck from the pit bottom to the truck. Waste disposal was accomplished by dumping into a flume, with water pumped from a small dam on a nearby branch.

The operations of R. G. LeTourneau Company at Corundum Hill used a bulldozer. The method consisted essentially of pushing the weathered dunite away from the exposed veins and pockets of vermiculite, loading these out by hand and then repeating the cycle. The hillside topography provides ample room for waste disposal and large boulders are easily removed. Considerable dilution would be expected from such a process, but the impurities are mostly in the fines and can be removed by screening either before or after exfoliation. The LeTourneau Company also mined some vermiculite by sinking an eight-foot circular boiler plate caisson in a verm-

FIG. 4. NO. 1 PIT OF BEE TREE VERMICULITE MINES.

iculite zone to a depth of about 12 feet, thus supporting the walls and permitting the ready removal of the vermiculite.

The operations of the Bee Tree Vermiculite Company, near Tigerville, South Carolina, use a bulldozer for mining, with considerable success.

It is believed that the use of a bulldozer will be of increasing importance in future mining.

PROCESSING OF VERMICULITE[23]

Vermiculite processing plants have been operated at Ellijay and Franklin in Macon County and Swannanoa in Buncombe County. The Cary Minerals Company plant at Ellijay has not been operated since 1941 and part of the Bee Tree Vermiculite Company plant has been moved to Tigerville, South Carolina, where it has operated

[23] Murdock, T. G., op. cit.

since 1943; essentially the same flow-sheet, with some minor improvements, is in use. The plant at Franklin operated part time during the war, however the Vercalite Industries, Inc. is now on a full-time schedule.

The flow sheet of the screening plant of the Cary Minerals Company operation was quite simple. The plant (see fig. 5) was constructed on a hillside and the crude vermiculite moved by gravity from the bin at the end of the tram lines from the nearby mine workings to the storage shed and loading platform. The rotary drier used was 4 feet in diameter, 20 feet long, and inclined at a 3½° angle. It revolved slowly and was wood-fired, the temperature being insufficient to cause exfoliation. From the lower end of the drier the vermiculite fed into a small Sturtevant crusher, discharging into a revolving screen four feet in diameter, 18 feet long. The screen was divided into 18 panels and made a classification of six sizes.

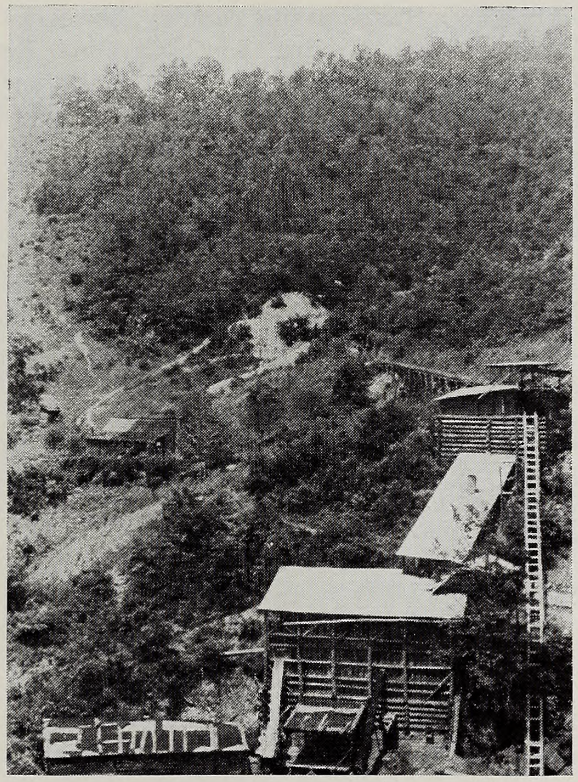


Fig. 5. Screening Plant of Cary Mineral Co., Ammons Mine.

At the plant of Bee Tree Vermiculite Mines both screening and exfoliation was carried out. These operations are shown in detail in the accompanying flow-sheet (see fig. 6). The drying was carried out in a rotary kiln, 3 feet in diameter and 20 feet long. Fuel oil was used and consumption was 2 to 2-½ gallons per hour, depending upon the moisture content of the crude vermiculite, and the quantity dried was between ¾ ton and 3 tons per hour. The crusher was of the type commonly used in crushing tan bark and had a maximum capacity of 5 tons per hour. The screening plant (see fig. 7) employed vibrating screens for the largest sizes. The 40-mesh screen was a fixed one, discharging overs to the fines bin. The expander was a shaft furnace, approximately 20 inches square in cross-section and rising to a height of 22 feet. The falling feed passed over staggered baffles and upon coming in contact with the ascending heat from an oil-fired burner, at a temperature of 2,000°F., exfoliated or opened up into the characteristic accordion-like porous granules, the result of the transformation into steam of the combined water in the crude vermiculite. The continuation of the fall of the expanded material to the bottom of the shaft brought about quick cooling and thus rendered it tough and pliable. The different sizes were exfoliated separately for best results, and to avoid any tendency of the larger sizes to insulate the smaller ones and prevent their exfoliation. The expander consumed 6-½ to 7-½ gals. of fuel oil per hour and its normal capacity varied between 40 and 48 bags of finished product per hour, each bag weighing

25 pounds and containing approximately 4 cubic feet. A cyclone was placed at the top of the expander and the finer particles of "stack dust" were collected in this way. When house fill and concrete aggregate sizes were being expanded the fines blown out into the cyclone amounted to about 4 cubic feet per hour. An 8-mesh oscillating screen, driven by a small motor, was placed between the expander and the sacking shed, in a chute leading from the top of the bucket elevator at the foot of the expander. Electric power was used throughout the plant—the vibrating screens and bucket elevators being driven by 1-½ hp. motors; the screw conveyor and the drier by a 7½ hp. motor; and the crusher and drag conveyor by a 5-hp. one.

VERMICULITE DEPOSITS IN OTHER STATES

Vermiculite has been reported in eleven States in this country, however the principal commercial developments have been in Colorado, Montana, North Carolina, South Carolina, Pennsylvania, and Wyoming. The greater part of the production has come from Montana, from the operations of the Zonolite Company, in the Rainy Creek district near Libby. According to Pardee and Larsen[24] the deposits occur in a stock of alkaline

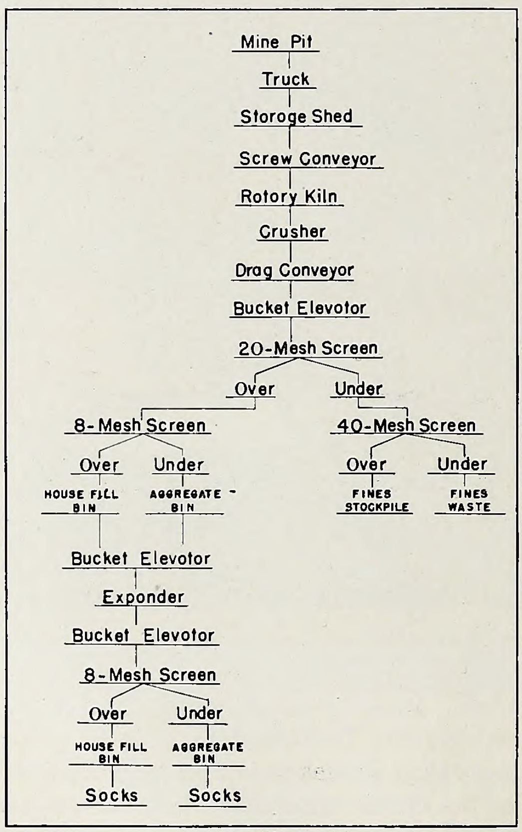


FIG. 6. FLOW SHEET USED AT BEE TREE PLANT.

rocks that is intruded into Algonkian argillites and quartzites. The operations of the Zonolite Company have been described by Steele.[25] Several promising occurrences of vermiculite have been reported from Colorado and Alderson[26] has described those near Salida, Iola, and Westcliffe. The jefferisite variety occurs in the Brinton serpentine quarry, near West Chester, Pennsylvania; the deposit was worked in 1929 by John Warren Watson

[24] Pardee, J. T., and Larsen, E. S., Deposits of vermiculite and other minerals in the Rainy Creek district near Libby, Montana: U. S. Geol. Survey Bull. 805-B, pp. 1-12, 1929.
[25] Steele, W. S., Vermiculite production and marketing by the Zonolite Company: Am. Inst. Min. Eng. Trans., vol. 109, pp. 418-426, 1934.
[26] Alderson, V. C., Jefferisite: Colorado School of Mines Inf. Circ., 4 pp., undated.

Company of Philadelphia. Some production was reported in 1931 by the Parco Development Company, from a property near Encampment, Wyoming. Vermiculite occurrences in Georgia have been reported by Smith,[27] and later by Prindle.[28]

Since 1943 the Bee Tree Vermiculite Company has been exploiting two of five known deposits, about 1 mile east of Tigerville, Greenville County, South Carolina. These deposits have been prospected by shafts and by auger borings. The widths of their outcrops range from 40 to 175 feet; the lengths range from 150 to 800 feet. In some shafts, good quality vermiculite has been found to a depth of 45 feet. The occurrence, a result of the alteration of pyroxenite lenses in the Carolina gneiss, is an unusual one; the entire mass of pyroxenite has been

FIG. 7. SCREENING PLANT, BEE TREE VERMICULITE MINES.

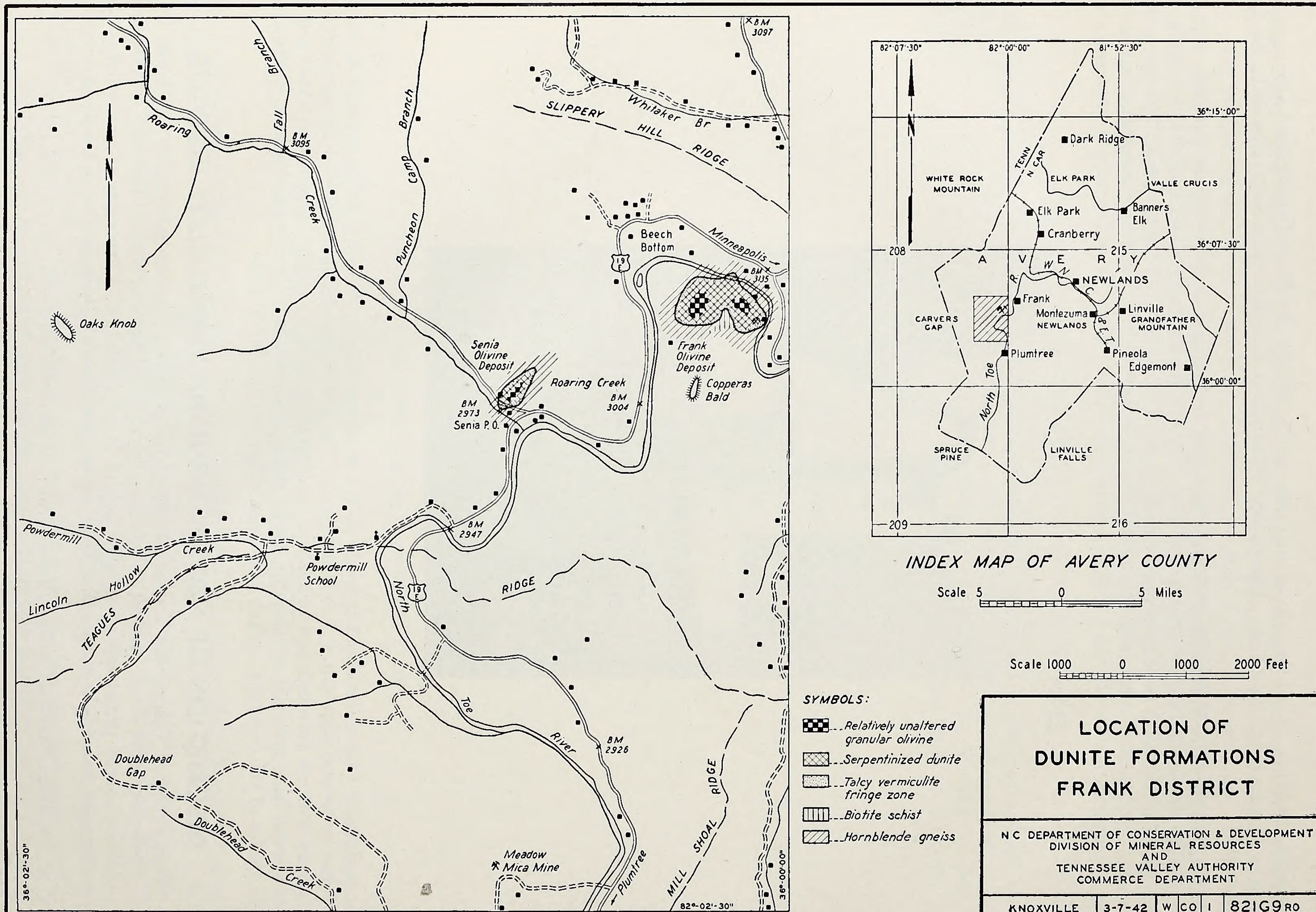
altered so completely that it is difficult to locate even a small remnant. The vermiculite exposed by mining operations is cut by several pegmatites, 1 to 3 feet thick. The rather complete alteration of the pyroxenite has resulted in a very uniform vermiculite which is well adapted to low-cost mining by open-cut methods and the production of a small flake material suitable for use as concrete aggregate. Vermiculite reserves in the area within a 1-mile radius of the company's plant have been estimated at 300,000 tons.

DESCRIPTION OF NORTH CAROLINA VERMICULITE DEPOSITS

For convenience of description the occurrences are discussed by counties (which are taken up alphabetically). However, most of the production has been from Buncombe and Macon Counties. The deposits have been named from nearby prominent geographic points, or are identified by the name of the owner of the property where they are found. In most cases these names coincide with those applied to the same occurrences in

[27] Smith, R. W., Vermiculite, the heat insulator of tomorrow: Georgia Div. Geology Inf. Circ. 3, p. 2, 1934.
[28] Prindle, L. M. Kyanite and vermiculite deposits of Georgia: Georgia Geol. Survey Bull. 46, pp. 41-45, 1935.

PLATE 3


LOCATION OF
DUNITE FORMATIONS
FRANK DISTRICT
N C DEPARTMENT OF CONSERVATION & DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT
KNOXVILLE
3-7-42
W
CO
I
821G9RO
INDEX MAP OF AVERY COUNTY
Scale 5 0 5 Miles
Scale 1000 0 1000 2000 Feet
SYMBOLS:
Relatively unaltered granular olivine
Serpentinized dunite
Talcy vermiculite fringe zone
Biotite schist
Hornblende gneiss
82°07'30"
82°00'00"
81°52'30"
36°15'00"
36°07'30"
36°00'00"
208
215
209
216
WHITE ROCK MOUNTAIN
TENN
N CAR
Dark Ridge
ELK PARK
VALLE CRUCIS
Elk Park
Banners Elk
Cranberry
A V E R Y
NEWLANDS
Frank
Montezuma
NEWLANDS
Linville
GRANDFATHER MOUNTAIN
CARVERS GAP
Plumtree
Pineola
Edgemont
North Toe
SPRUCE PINE
LINVILLE FALLS
BM 3097
SLIPPERY HILL RIDGE
Whitaker Br
Roaring Creek
Fall Branch
BM 3095
Camp Branch
Puncheon
Beech Bottom
Minneapolis
BM 3135
Frank Olivine Deposit
Copperas Bald
Oaks Knob
Senia Olivine Deposit
Roaring Creek
BM 3004
BM 2973
Senia P.O.
BM 2947
Powdermill Creek
Powdermill School
Lincoln Hollow
TEAGUES
North Toe River
RIDGE
BM 2926
Doublehead Gap
Doublehead Creek
Meadow Mica Mine
Plumtree
MILL SHOAL RIDGE
36°02'30"
36°00'00"
82°02'30"

previous reports. The estimate of tonnage reserves is given by counties in a previous section of this report. Detailed results of the exfoliation tests, chemical analyses, and identification of the source of the samples are given in the Appendix.

AVERY COUNTY

FRANK DEPOSIT

The Frank deposit is ¼ mile west of the Frank Post Office, on U. S. Highway 19-E (see pl. 3).[29] The vermiculite is associated with anthophyllite zones in a dunite mass approximately 1,400 feet long and 400 feet wide. The development consists of several small open cuts which expose asbestos and vermiculite. One carload of vermiculite was shipped from this deposit in 1936. The exploitation of the property appears to be possible only through the production of by-product anthophyllite.

UNPROVEN LOCALITIES

Small bodies of olivine, with some chlorite, are found near Senia Post Office and north and east of Frank. It might be advisable to prospect these localities.

BUNCOMBE COUNTY

BEE TREE DEPOSIT

The Bee Tree deposit is about 2½ miles north of Swannanoa and a short distance south of Asheville City Bee Tree water reservoir (see pl. 4).

The development here consists of three principal workings. All the production in this area has been from open cuts. The largest of these is found on a hill to the east of the home of H. A. Coggins and a short distance south of Spruce Branch. This cut, about 75 feet in diameter, has been almost entirely in vermiculite which occurs along the contacts of a pyroxenite mass (see pl. 5). Several small pits along the strike to the northeast of the largest cut have encountered good quality vermiculite.

About 1,300 feet northwest of this cut and near Bee Tree Dam is another open cut, on the northwest limb of the pyroxenite mass. This latter cut has exposed several zones of vermiculite 8 to 12 feet in width and occurring as interior veins in pyroxenite (see pl. 6). Numerous small pits and trenches have shown the presence of vermiculite to the northeast of this cut.

About ¾ mile southwest of Bee Tree Dam and on the north side of Bee Tree Creek, there occurs an excellent prospect. The vermiculite at this point is exposed by an erosion ditch and prospect pits along the eastern border of the lens.

Perhaps 50 percent of the vermiculite in the Bee Tree area is suitable for house-fill material.

The principal associated minerals in the Bee Tree area are chlorite and actinolite. Hornblende inclusions are found in several places.

LAKE EDEN DEPOSIT

The Lake Eden deposit is ¾ mile southeast of the Bee Tree. This property has been developed by an open cut, which exposes commercial grade orthoclase and muscovite in a pegmatite. A small amount of vermiculite occurs at the contact between altered pyroxenite and the pegmatite. It is possible that commercial grade vermiculite might be found along the contact zone to the northeast and southwest of the workings as only a small amount of prospecting has been done there. This property, however, has greater merit for its mica and feldspar; it has been exploited for these minerals, both some years ago and more recently.

OTHER LOCALITIES

There are a few unproven localities in Buncombe County where some prospecting seems advisable. For example there are peridotite and pyroxenite areas between Swannanoa and Oteen; dunite masses are near Democrat and Newfound Gap; and, serpentine occurs in the Juno area.

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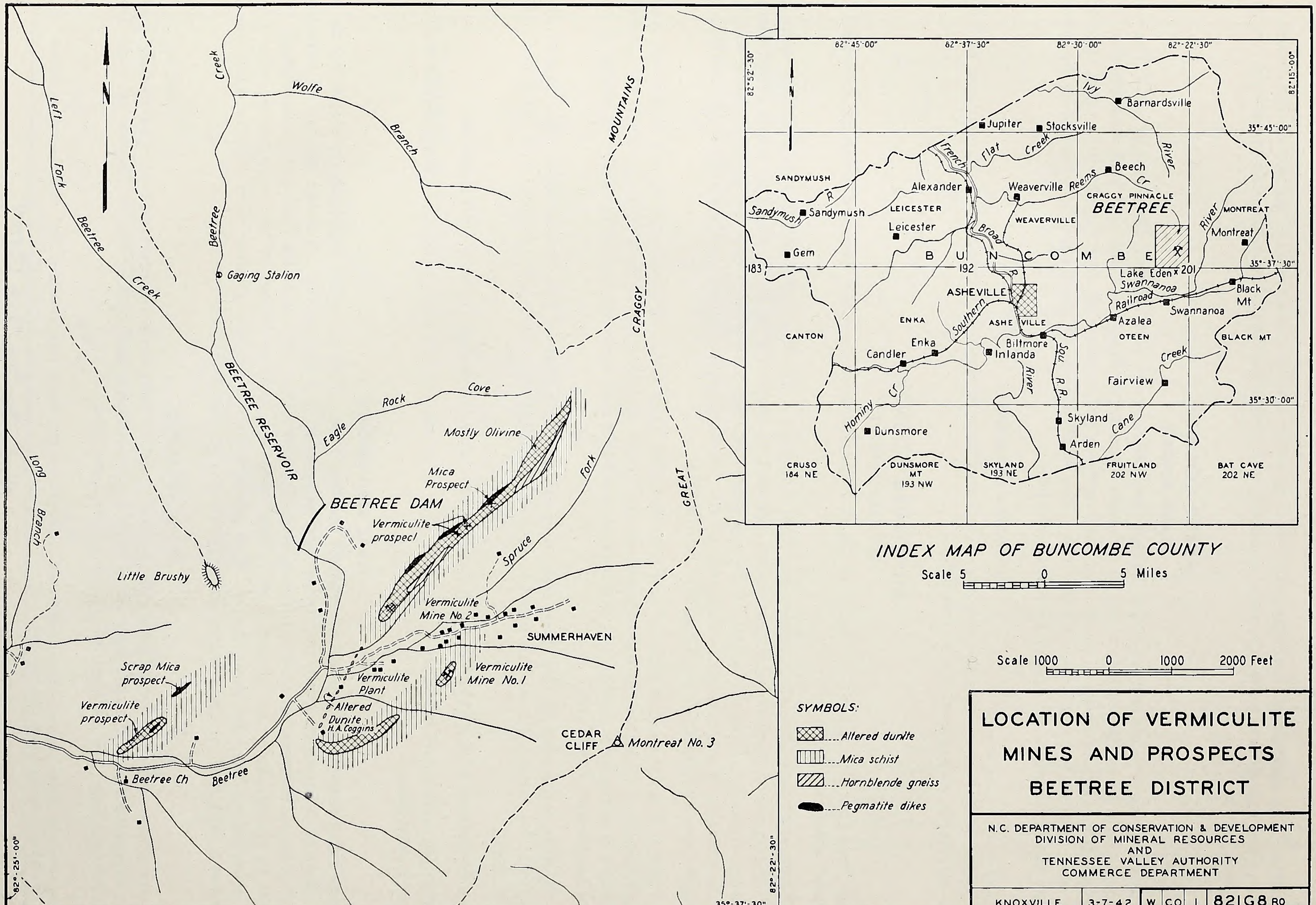
[29] Quadrangles shown in index map of Avery County, and in other county maps following are 7½′ quadrangles prepared by Tennessee Valley Authority on scale of 1:24,000.

PLATE 4



LOCATION OF VERMICULITE
MINES AND PROSPECTS
BEETREE DISTRICT
N.C. DEPARTMENT OF CONSERVATION & DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT
KNOXVILLE | 3-7-42 | W | CO | I | 821G8 RO
INDEX MAP OF BUNCOMBE COUNTY
Scale 5 0 5 Miles
Scale 1000 0 1000 2000 Feet
SYMBOLS:
Altered dunite
Mica schist
Hornblende gneiss
Pegmatite dikes
BEETREE DAM
BEETREE RESERVOIR
Gaging Station
Mostly Olivine
Mica Prospect
Vermiculite prospect
Vermiculite Mine No 2
Vermiculite Mine No. 1
Vermiculite Plant
Altered Dunite
H. A. Coggins
SUMMERHAVEN
CEDAR CLIFF
Montreat No. 3
Scrap Mica prospect
Beetree Ch
Little Brushy
Left Fork Beetree Creek
Long Branch
Wolfe Branch
Eagle Rock Cove
Spruce Fork
Beetree Creek
GREAT CRAGGY MOUNTAINS
82°-25'-00"
82°-22'-30"
35°-37'-30"
SANDYMUSH
LEICESTER
WEAVERVILLE
CRAGGY PINNACLE
BEETREE
MONTREAT
ASHEVILLE
ENKA
CANTON
OTEEN
BLACK MT
CRUSO 184 NE
DUNSMORE MT 193 NW
SKYLAND 193 NE
FRUITLAND 202 NW
BAT CAVE 202 NE
Barnardsville
Jupiter
Stocksville
Alexander
Weaverville
Beech
Sandymush
Leicester
Gem
Montreat
Lake Eden
Black Mt
Swannanoa
Azalea
Biltmore
Inlanda
Enka
Candler
Fairview
Skyland
Arden
Dunsmore
B U N C O M B E

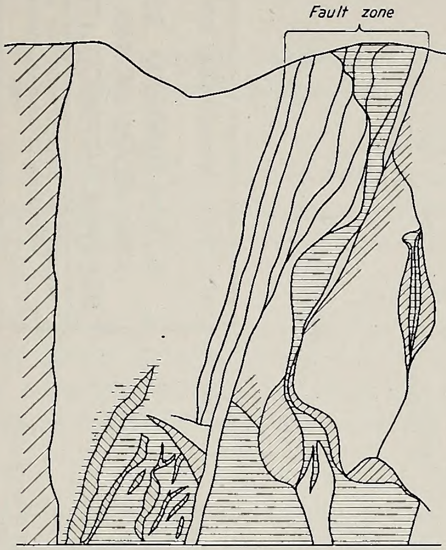


FIG A
CROSS SECTION OF CONTACT VEIN
TAKEN N 20° E

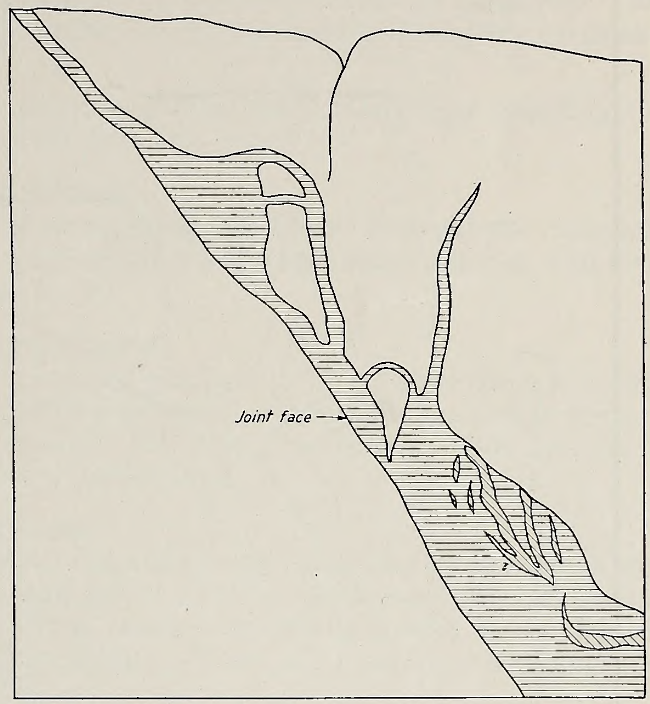


FIG B
CROSS SECTION OF INTERIOR VEIN
TAKEN PARALLEL TO JOINT FACE - S 68° E

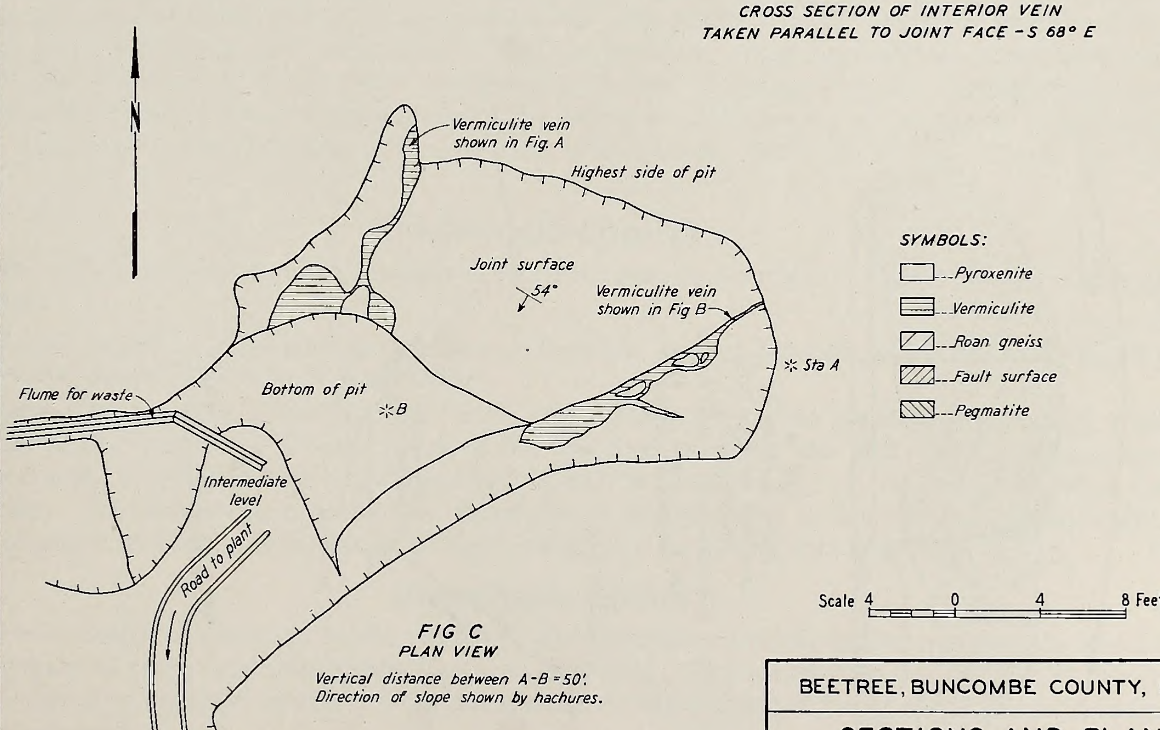


FIG C
PLAN VIEW
Vertical distance between A-B = 50'.
Direction of slope shown by hachures.

REV. NO.	DATE	MADE	CHKD.	SUPV.	INSP.

DRWN.______ COMPUTED
TRCD. HPL ENGINEER
CHKD.______

BEETREE, BUNCOMBE COUNTY, N. C.

SECTIONS AND PLAN
NO. 1 PIT
BEETREE VERMICULITE MINES

N C DEPT OF CONSERVATION AND DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT

KNOXVILLE	4-16-42	W	CO	1	821G16 RO

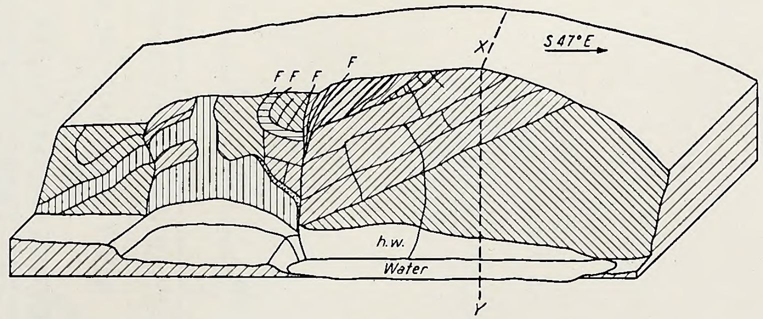


FIG. A
BLOCK DIAGRAM OF
N.E. SIDE OF NO. 2 PIT
TAKEN N 43° E
Cross section along X-Y shown in Fig B
Scale 4 0 4 Feet

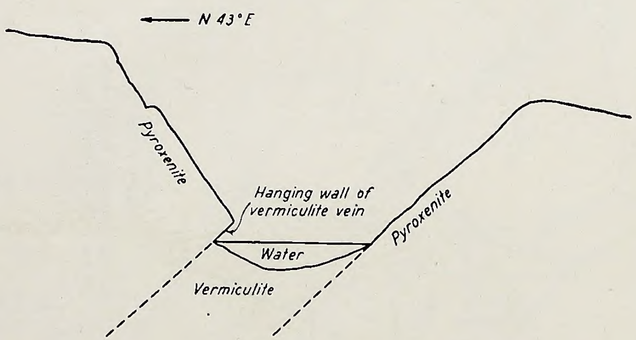


FIG. B
Scale 4 0 4 Feet

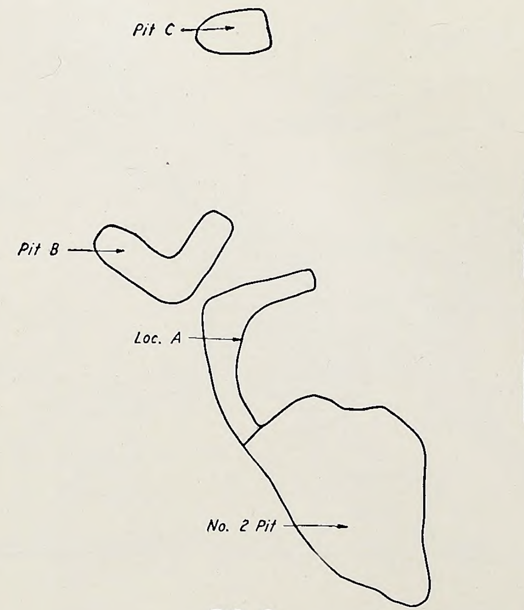


FIG. C
PLAN VIEW OF NO. 2
AND ASSOCIATED PITS
Scale 10 0 10 Feet

SYMBOLS:
- ...Pyroxenite
- ...Altered pyroxenite
- ...Vermiculite
- ...Chlorite
- ...Actinolite
- hw Hanging wall of vermiculite vein along joint.

REV. NO.	DATE	MADE	CHKD	SUPV.	INSP.
DRWN.......	COMPUTED				
TRCD. D.M.D.	ENGINEER				
CHKD.......					

BEETREE BUNCOMBE COUNTY, N.C.

BLOCK DIAGRAM, SECTION AND PLAN OF NO. 2 PIT BEETREE VERMICULITE MINES

N.C. DEPT OF CONSERVATION AND DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT

KNOXVILLE	4-16-42	W	CO	1	821G14 RO

CLAY COUNTY

As in other counties, the vermiculite of Clay County is found in association with the peridotites. These basic formations are found only in the eastern part of the county, on the headwaters of Shooting Creek and of Buck Creek.[30]

Prospecting for vermiculite has been carried out at several localities, particularly near Shooting Creek Post Office. Some commercial shipments have been reported from this county.[31]

MARK ROGERS PROPERTY

The Mark Rogers property is 1-½ miles southeast of Shooting Creek Post Office. Prospect pits expose small veins of fair quality vermiculite along the east contact of a pyroxenite mass; poorer grade material, occurring as a six-foot vein, is exposed on the west contact of the mass.

BARNETT ANDERSON PROPERTY

To the south of the Mark Rogers property and approximately ¼ mile N.13°W. from the Barnett Anderson home on Giesky Creek, a single pit has been sunk, on the eastern contact of a pyroxenite mass with gneiss. A 5-foot zone of a vermiculite-like schistose material is exposed 6 feet from the contact. This material was sampled as representative of that frequently mistaken for true vermiculite.

OTHER LOCALITIES

One mile from the mouth of Thumping Creek and 3 miles east of Shooting Creek Post Office, vermiculite occurs as small lenticular masses on either side of a hypersthene dike. According to Bryson[32] "this dike extends some little distance across the hills and valleys and at one or two places cross-cutting showed vermiculite zones of 15 or 20 feet with a length a little greater. At one place a depth of 35 feet was reached without any change in the material."

Two and one-half miles up Buck Creek and near the top of the rugged Nantahala Mountains, large masses of dunite suggest possible localities for future exploration. The dunite deposit consists of a series of intrusions, some of which have undergone much alteration.[33] It is cut by many small pegmatites, which have apparently contributed to the alteration of parts of the dunite into chlorite. It appears highly possible that development along the contacts and interior zones of weakness of the dunite would locate some commercial vermiculite. Pratt and Lewis[34] definitely record the occurrence of both wilcoxite and dudleyite at Buck Creek, the latter very sparingly.

HAYWOOD COUNTY

Pratt and Lewis[35] mention a minor occurrence of vermiculite at Retreat, on Pigeon River, 6 miles southeast of Waynesville:

> The rocks are saprolitic garnetiferous gneisses and schists, cutting through which are many small permatites accompanied by seams of vermiculite.

In the approximate center of the Hominy Grove dunite mass, 2-½ miles northeast of Canton, which is approximately 2,000 feet long and 200 feet wide with the long axis trending east and west[36], a single vermiculite occurrence is found. The flakes which are less than ¼ inch in diameter and exfoliate slightly when heated are mixed with clay. The vermiculite could not be traced, but it is apparently an interior vein which might develop into a small commercial body. Some kaolin present indicates a permatite intrusion.

HENDERSON COUNTY

About 2 miles south of Zirconia, to the north of Lake Summit, a potash feldspar pegmatite containing disseminated crystals of zircon and xanthitane has been exploited. This pegmatite has furnished the entire domestic production of commercial zircon.[37] It is intruded along the contact of fine-grained hornblende gneiss and

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[30] Pratt, J. H. and Lewis, J. V., op. cit., pp. 36-38.
[31] Smith, Richard W., op. cit., p. 3.
[32] Bryson, H. J., Letter in files of State Geologist, 1936.
[33] Hunter, C. E., op. cit., p. 108.
[34] Pratt, J. H., and Lewis, J. V., op. cit., p. 322.
[35] Pratt, J. H., and Lewis, J. V., op. cit., p. 256.
[36] Hunter, C. E., op. cit., p. 65.
[37] Pratt, J. H., Zircon, monazite and other minerals: North Carolina Geol. and Econ. Survey Bull. 25, p. 19, 1916.

mica schist. Large books of micaceous material are found along the contact, and in fractured interior zones. This material appears to have been biotite originally; it delaminates freely in the flame of a match. Along the south side of Lake Summit a biotite schist crops out over a maximum thickness of 50 feet and lies adjacent to granite. Much of the exposed schist has been altered to a vermiculite-like material and some flakes of this have a maximum diameter of 1/4 inch. This material is mixed with quartz, feldspar, and kaolin. The Lake Summit occurrences have none of the characteristics of those of a true vermiculite; they are as typical books in a regular pattern in a pegmatite, rather than as veins, pockets, or lenses of individual interlocking crystals like those of chlorite, in basic magnesian rocks. The exfoliation tests indicate the material from both localities at Lake Summit has none of the desired qualities of vermiculite.

IREDELL COUNTY

Vermiculite is found at the following localities near Statesville: At Hunters, 7 miles to the west, in a dark green amphibolite accompanying corundum and chlorite; at the Acme corundum mine, 1-1/2 miles to the west; and on the Plyler farm, 7 miles to the northeast, in a mass of impure soapstone. These occurrences are as a minor associated mineral and none of them are considered of any commercial importance.

JACKSON COUNTY

ADDIE DISTRICT

Vermiculite occurs rather widely throughout the Addie dunite mass, which extends 3/4 mile northwest and slightly more than 1 mile south of the Addie railroad station. This formation attains its maximum width of 2,000 feet at a point 1/4 mile south of the station, and constitutes the eastern part of a series of saxonite and dunite intrusions which occur as an elliptical-shaped ring. This ring has a long axis of about 6 miles and a short axis of about 3-1/2 miles (see pl. 7).

FISHER PROPERTY

The main body of the Addie dunite mass, the major part of which is known as the Fisher property, lies between Scott and Ocher Creeks. Numerous veinlets of vermiculite crop out along the secondary road southeast of the Fisher home, especially where the road passes through the zone of relatively unaltered olivine. These exposures are made up of both first-class and low-grade vermiculite, accompanied by talc and some pegmatite material . A prospect trench runs S.35°E. from the road for approximately 600 feet; the southeast third of this trench exposes an almost continuous series of vermiculite veins. Vermiculite has been found in a number of scattered tests pits located on a hill about 1/4 mile west of the trench. These openings are between a schist inclusion and the western boundary of the dunite mass, in adjoining areas of unaltered olivine and serpentinized dunite. Conditions are favorable for additional prospecting around the perimeter of the schist inclusion in the approximate center of the dunite deposit.

Vermiculite occurs in two nickel prospect pits in this area, one of which is located about 900 feet south of the Fisher home and shows a 14-inch vein of large flake material extending from the surface to a depth of 20 feet. Several veins, reaching a maximum of 2 feet in width, are to be seen in association with a pegmatite in the bank of a tributary flowing northwest into Scott Creek, about 200 feet north of the road. On the south bank of Scott Creek, opposite the railroad siding, a series of vermiculite veins is exposed over a length of 125 feet, extending to within 50 feet of the east contact.

OCHER CREEK DISTRICT

The southern part of the Addie dunite mass narrows to about 400 feet in width and crops out along a steep bluff overlooking Ocher Creek to the southwest. A gravel road passes through the center of this section of the formation and follows a zone of interior vermiculite veins (see figs. 8 and 9). These veins are exceptionally closely spaced; some of them reach 2 feet in thickness. In 2600 feet of road cut, the width of vermiculite exposures totals 40 feet or 1.5 percent; approximately half of this is of first-class flake size and grade. The better grades of vermiculite are seen only in a zone about 20 feet wide, approximately 400 feet north of the point where the road crosses a small tributary of Ocher Creek and turns sharply south to cross the southwest contact. Vermiculite is also exposed in a branch road, southwest of the main road.

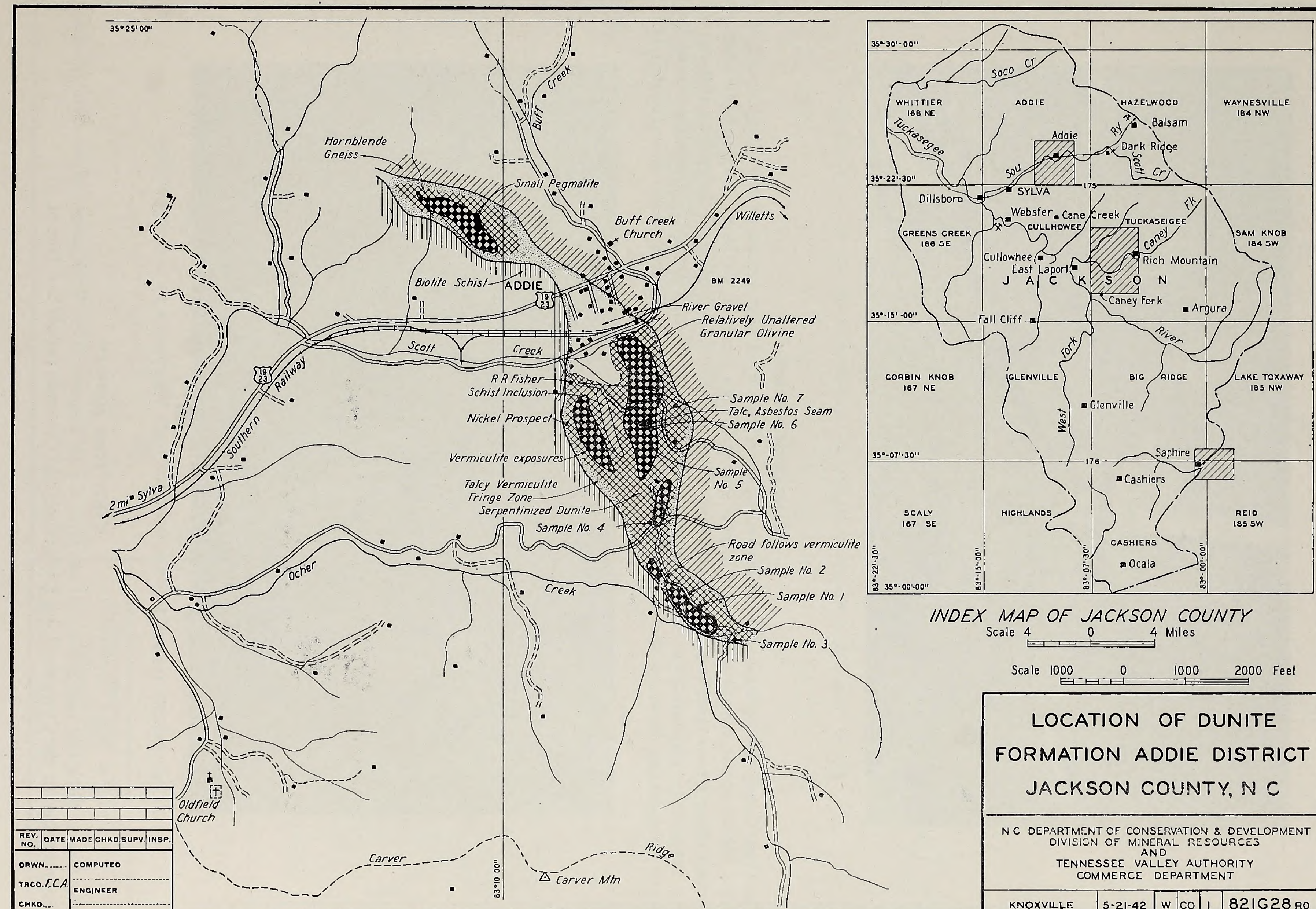

35°25'00"
83°10'00"
Hornblende Gneiss
Small Pegmatite
Buff Creek
Buff Creek Church
Willetts
Biotite Schist
ADDIE
19 23
BM 2249
River Gravel
Relatively Unaltered Granular Olivine
Scott
Creek
Southern Railway
2 mi Sylva
R R Fisher Schist Inclusion
Nickel Prospect
Vermiculite exposures
Talcy Vermiculite Fringe Zone
Serpentinized Dunite
Sample No. 4
Sample No. 7
Talc, Asbestos Seam
Sample No. 6
Sample No. 5
Road follows vermiculite zone
Sample No. 2
Sample No. 1
Sample No. 3
Ocher
Creek
Oldfield Church
Carver
Ridge
Carver Mtn
REV. NO. | DATE | MADE | CHKD. | SUPV. | INSP.
DRWN.
TRCD. F.C.A.
CHKD.
COMPUTED
ENGINEER
35°-30'-00"
35°-22'-30"
35°-15'-00"
35°-07'-30"
35°-00'-00"
83°-22'-30"
83°-15'-00"
83°-07'-30"
83°-00'-00"
Soco Cr
WHITTIER 168 NE
ADDIE
HAZELWOOD
WAYNESVILLE 184 NW
Tuckasegee
Addie
Balsam
Ry
Dark Ridge
Scott Cr
Sou
SYLVA
175
Dillsboro
Webster
Cane Creek
CULLHOWEE
TUCKASEIGEE
Fk
Caney
GREENS CREEK 168 SE
SAM KNOB 184 SW
Cullowhee
East Laport
Rich Mountain
J A C K S O N
Caney Fork
Argura
Fall Cliff
River
CORBIN KNOB 167 NE
GLENVILLE
BIG RIDGE
LAKE TOXAWAY 185 NW
Glenville
West Fork
Saphire
176
Cashiers
SCALY 167 SE
HIGHLANDS
CASHIERS
REID 185 SW
Ocala
INDEX MAP OF JACKSON COUNTY
Scale 4 0 4 Miles
Scale 1000 0 1000 2000 Feet
LOCATION OF DUNITE
FORMATION ADDIE DISTRICT
JACKSON COUNTY, N C
N C DEPARTMENT OF CONSERVATION & DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT
KNOXVILLE | 5-21-42 | W | CO | 1 | 821G28 R0

FIG. 8. VERMICULITE FILLING OF MAJOR JOINT IN SERPENTINIZED DUNITE, OCHER CREEK.

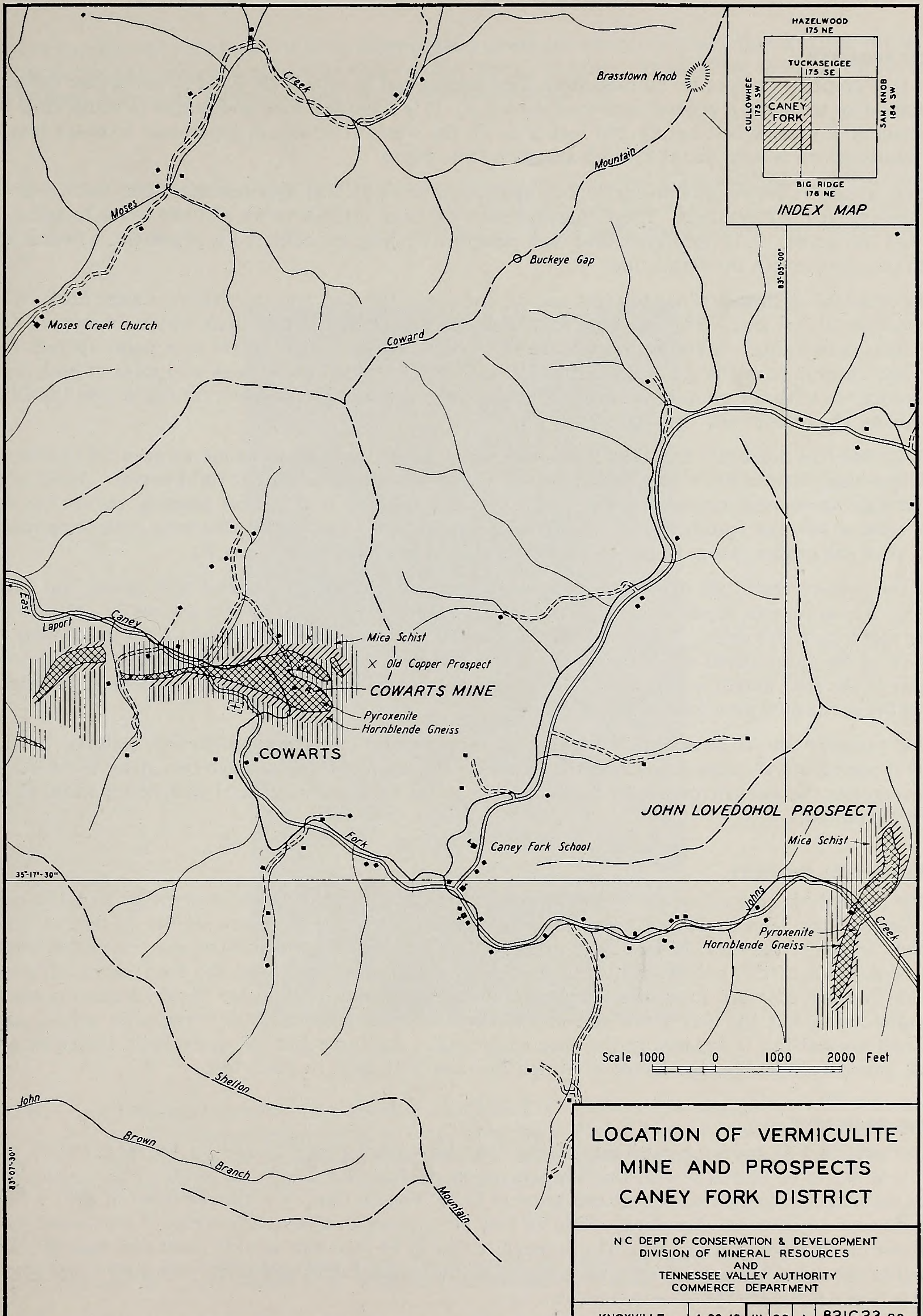
CANE CREEK DISTRICT

The Cane Creek olivine mass, 3-½ miles southeast of Sylva, is also a part of the Webster-Addie ring dike structure. Most of the vermiculite found in pits and road cuts north of the Mary Hooper home indicates that it was formed along a zone trending north-northeast. Ten percent of the flakes are large; the rest are very small. Kyanite frequently accompanies the vermiculite along the southeast contact. There has been only a small amount of prospecting, however the existence of a small, possibly productive zone, is suggested.

FIG. 9. TYPICAL JOINTING OF DUNITE WITH VERMICULITE FILLING, OCHER CREEK.

CANEY FORK DISTRICT

The Caney Fork District is east of the town of East Laport on the Tuckasegee River. Vermiculite prospects have been opened at the Cowarts, John Lovedohol, and Cowards properties (see pl. 8).



LOCATION OF VERMICULITE MINE AND PROSPECTS CANEY FORK DISTRICT

N C DEPT OF CONSERVATION & DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT

KNOXVILLE	4-30-42	W	CO	I	821G23 RO

COWARTS PROPERTY

At this property, 3-½ miles by road from East Laport and ¼ mile N.39° E. of Cowarts Post Office, a large pyroxenite dike trends in a general east-west direction. It is 3,400 feet long and ranges in width from 800 feet on the east to a narrow belt hardly 100 feet wide on the west. The dike is apparently intruded into a hornblende gneiss which is surrounded by mica schist.

There are eight vermiculite prospects, in a general north-south line approximately 600 feet from the east end of the pyroxenite formation. These openings have explored interior zones and the contacts both with the gneiss and the schist. It is significant that each prospect working encountered a pegmatite of some shape or form, in association with the vermiculite.

The principal opening is about 400 feet east of, and about 100 feet vertically above, Caney Fork; it consists of an open cut 50 feet long. This cut runs N.82°E. to the portal of a 50-foot drift which follows a 3-foot vein of first-class vermiculite. A branch drift to the right turns off at a small angle at a point 15 feet from the portal, and roughly parallels the main drift. Vermiculite is exposed in the back and sides of both drifts, not continuously but with the usual admixtures of impurities. A section of the open cut taken over the drift at its portal shows the 3-foot vein (see fig. 10).

About 340 feet northeast from the main working in the northern contact zone, an open cut exposes a 5-foot vein of first-class vermiculite with a 7-foot vein of similar material joining it at right angles. About 50 percent of the cut face shows high-grade material. Approximately 140 feet west of this opening, also in the northern contact zone, a 100-foot trench trends N.50°W. and exposes a 10-foot vermiculite zone containing material of various sizes and grades; about 50 percent of this is of good and intermediate quality.

At the western end of the dike an old corundum drift runs S.70°E. Its portal is in gneiss, but further in, according to local reports, it passes through the contact. Several vermiculite veins are cut by a 60-foot crosscut running north from this drift. A 30-foot shaft at the face of the crosscut encounters a 2-½ foot vein. An examination of the dump shows much fine and schistose vermiculite, and pegmatite material. A series of old pits northeast of the drift mouth shows small veins of schistose vermiculite and some indications of vermiculite are found in the pyroxenite area west of the main dike.

This property shows considerable promise of a potentially important production, judging by the large amount of comparatively high-grade material exposed. The main opening and the two along the northern contact zone appear the most favorable for further development work and additional prospecting along all contacts appears warranted.

JOHN LOVEDOHOL PROPERTY

This property is approximately 2-¼ miles by road southeast of the Cowarts property and 1½ miles east of the Caney Fork School. Prospect cuts have been put down and a structure similar to that at Cowarts is indicated. In one of the cuts, 75 feet long and 8 feet deep, vermiculite is exposed over its entire length. On the southeast side of this cut several veins of relatively high-grade material are seen; some of these are 2 feet wide and are adjacent to weathered pyroxenite on both sides. Some clay impurities are present in the vermiculite veins, but the clay would not be expected at greater depths. A vermiculite schist, associated with small pegmatites, is exposed in the floor of the cut. An inspection of a stockpile indicates an intermediate grade vermiculite, the flakes of which average 3/16 inch in diameter.

COWARDS PROPERTY

This area is 1-½ miles by road east of the John Lovedohol property and on the headwaters of John's Creek; it is not to be confused with the Cowarts property about 4 miles to the west. The vermiculite occurrence is best exposed in a pit 4,000 feet northeast of Polly Wandin Gap, on a hill northeast of John's Creek, 300 feet northwest of Cowards Cemetery. This 30-foot pit exposes an alternating series of weathered pyroxenite and masses of vermiculite, 4 x 6 feet. The pyroxenite dike is 30 feet wide at this point and dips 20° NW. The vermiculite consists of masses of crystals, preserving the original structure of the pyroxenite joint blocks; each crystal is thus a pseudomorph after pyroxene.

Most of the exposed vermiculite is of an intermediate grade and size; any production will contain an excess of fines due to the disintegration of interlocking crystals upon crushing. Prospecting appears warranted just south of Cowards Cemetery where relatively fresh pyroxenite crops out.

OTHER LOCALITIES

About 2 miles south of Sylva vermiculite occurs at several places in the Webster peridotite. This peridotite is the largest of the Webster-Addie series;[38] it is crescent shaped and has a length of 2-3/4 miles and a maximum width of 1,800 feet. It is very well known because of the early experiments with associated nickel silicates.[39]

FIG. 10. VERMICULITE VEIN OVER DRIFT PORTAL, COWARTS MINE.

Indications are that the amount of vermiculite in this area is quite small in comparison with the other properties studied in detail, although prospecting, at least along the contacts, has not been widely done. It also appears that the vermiculite occurring in association with the nickel silicates, garnierite and genthite,[40] might be more important for its nickel content than for its usual properties.

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[38] Hunter, C. E., op. cit., p. 91.
[39] Pawel, G. W., Nickel in North Carolina: Eng. & Min. Jour., vol. 140, pp. 35-38, Oct. 1939.
[40] Ross, C S., Shannon, E. V., and Gonyer, F. A., Origin of nickel silicates at Webster, N. C., Econ. Geol., vol. 23, pp. 528-45, 1928.

MACON COUNTY

ELLIJAY DISTRICT

AMMONS PROPERTY

The Ammons property is in the western portion of the Moore's Knob dunite formation on the headwaters of Ellijay Creek, ¾ mile northeast of Ellijay and about ½ mile northeast of Moore's Knob (see pl. 9). This property was operated by the Cary Mineral Company between 1935 and 1941. Development work includes a shaft, drifts, and several open cuts (see pl. 10). The underground development work has a total length of over 1,100 feet. The vermiculite encountered in the workings has been mostly along interior structural weaknesses in the serpentinized dunite, as veins, pockets, and lenses.

The principal vermiculite production from the Ammons property has been from the shaft and the drifts in the central part of the formation. This shaft was caved at the time of the examination but it was reported to have been 96 feet deep with drifts at two levels. The drifts were irregular in both direction and grade, as an attempt had been made to follow the zones of vermiculite. These workings exposed veins of vermiculite as much as 15 feet wide and perhaps 125 feet long. Several vermiculite "pockets" were cut and these consisted of commercial grade material sometimes containing as high as 300 tons per "pocket". The greater part of the vermiculite was recovered by mining along the drift and in a limited amount of stoping. However, in no case was there a complete recovery of any of these "pockets", because of the inability to hold the heavy ground for sufficient time to remove the vermiculite.

The western contact area of the Ammons property has not been adequately prospected. A few short drifts and shallow pits show the presence of vermiculite in this area. Especially the contact between the dunite formation and the mica schist along the northwest area should be prospected.

Much associated pegmatite material is visible in most vermiculite veins exposed by the workings. At many points small lenses of actinolite are completely surrounded by vermiculite. Nickel silicate minerals are associated with a few of the vermiculite zones.

ANGEL PROPERTY

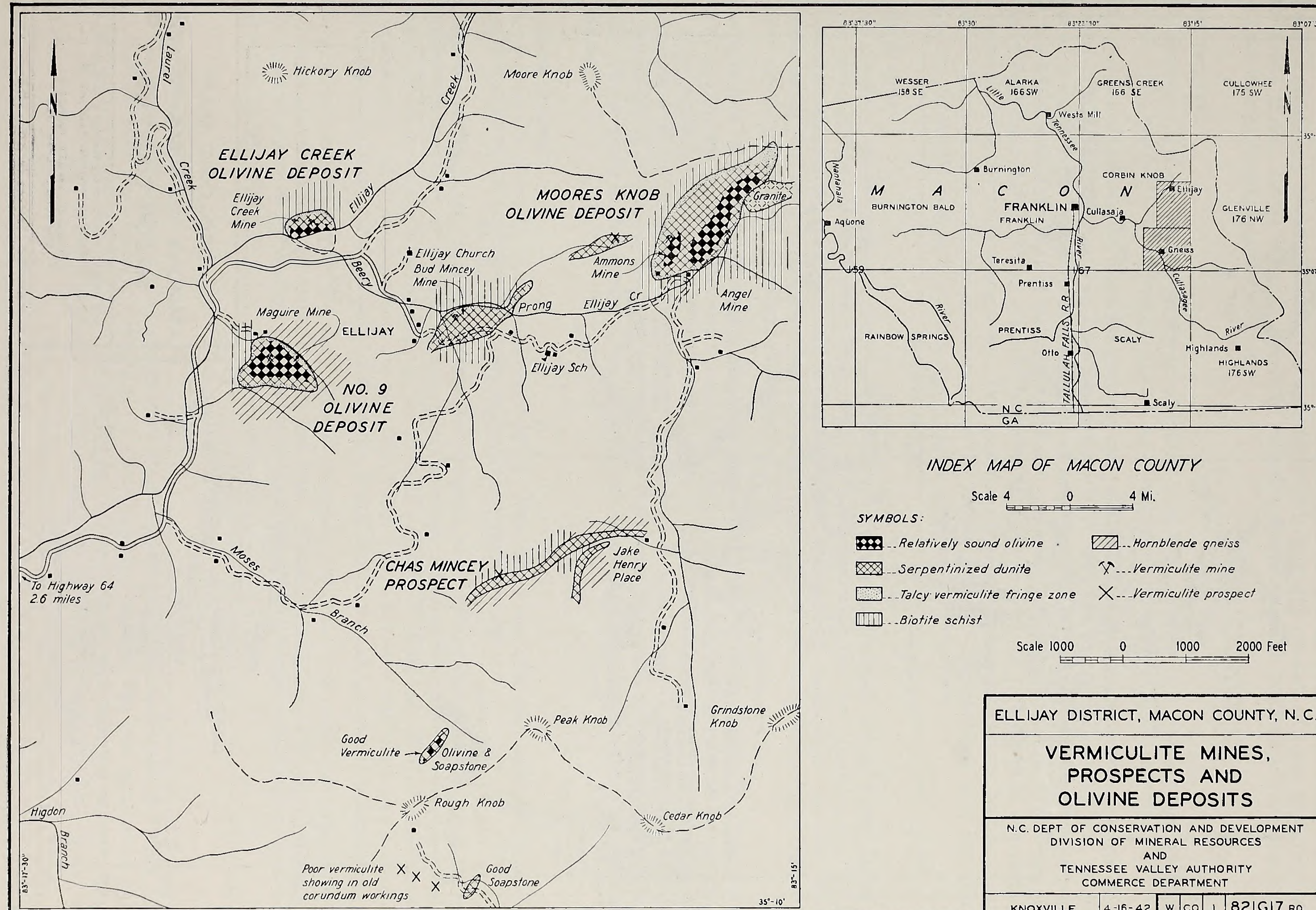
The Angel property, about 600 feet east of the Ammons mine, has been in intermittent production since 1935; it has been operated by Minerals, Incorporated, of Franklin, and its successor company. The original development was by shafts and drifts in search of corundum, and was done about 1890.

The geology of the Angel property is similar to that of the Ammons and, in fact, both properties are within the Moore's Knob dunite mass. The vermiculite production from this property has been from shafts, drifts, and open cuts (see pls. 11 and 12). Open cut mining has been rather extensively employed here and has yielded the greater part of the production. The open cuts are excavated along interior vermiculite veins and the work is continued in depth until the vermiculite pinches out or the walls of the cut become too difficult to hold. Some of the cuts have reached a depth of 35 feet.

Some of the underground workings at the Angel property have exposed inclusions of mica schist and gneiss within the dunite formation. In the western part of this property much excellent vermiculite was found around these inclusions.

The eastern contact zone of this formation has not been prospected. This should be done because vermiculite is found in the surface soil there. Minerals associated with the vermiculite veins on the Angel property include brownish actinolite, green chlorite, and locally, considerable garnierite and genthite.

Recent drifting, a short distance southwest of the most southwestern openings, has encountered a 5-foot vein of vermiculite along the wall of a schist inclusion, and at an elevation below that of the other workings. This inclusion may prove to be an extension of the one found in the large open cut (No. 11) and the adjacent drift, about 400 feet to the northeast (see pl. 11). If this is true, an important mineralization may occur along this contact.

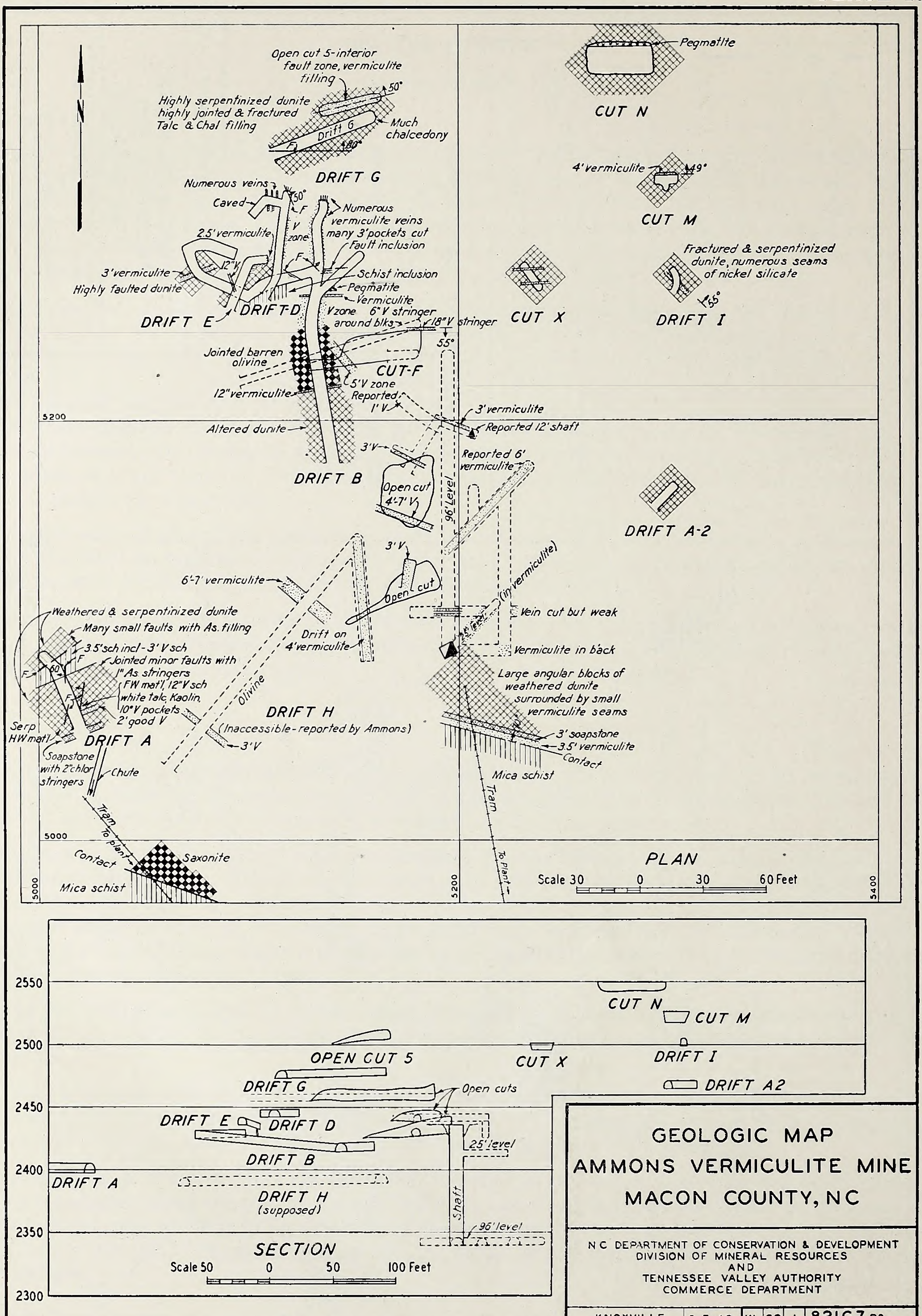


ELLIJAY DISTRICT, MACON COUNTY, N. C.

VERMICULITE MINES, PROSPECTS AND OLIVINE DEPOSITS

N.C. DEPT OF CONSERVATION AND DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT

KNOXVILLE	4-16-42	W	CO	1	821G17 RO


N
Open cut 5-interior fault zone, vermiculite filling
Highly serpentinized dunite highly jointed & fractured Talc & Chal filling
Much chalcedony
Drift G
DRIFT G
Numerous veins
Caved
2.5' vermiculite
V zone
Numerous vermiculite veins many 3' pockets cut
Fault inclusion
Schist inclusion
Pegmatite
Vermiculite
3' vermiculite
Highly faulted dunite
DRIFT E
DRIFT-D
V zone 6" V stringer around blks
18" V stringer
Jointed barren olivine
CUT-F
5' V zone
12" vermiculite
Reported 1' V
3' vermiculite
Reported 12' shaft
Altered dunite
DRIFT B
Reported 6' vermiculite
Open cut 4'-7' V
96' Level
6'-7' vermiculite
Open cut
(in vermiculite)
Vein cut but weak
Drift on 4' vermiculite
Vermiculite in back
Weathered & serpentinized dunite
Many small faults with As. filling
3.5' sch incl - 3' V sch
Jointed minor faults with 1" As. stringers
FW mat'l, 12" V sch white talc, Kaolin, 10" V pockets
2' good V
Olivine
DRIFT H
(Inaccessible - reported by Ammons)
3' V
Serp HW mat'l
DRIFT A
Soapstone with 2" chlor stringers
Chute
Large angular blocks of weathered dunite surrounded by small vermiculite seams
3' soapstone
3.5' vermiculite
Contact
Mica schist
Tram
To plant
Contact
Saxonite
Mica schist
Pegmatite
CUT N
4' vermiculite
CUT M
CUT X
Fractured & serpentinized dunite, numerous seams of nickel silicate
DRIFT I
DRIFT A-2
PLAN
Scale 30 0 30 60 Feet
5200
5000
5400
2550
2500
2450
2400
2350
2300
CUT N
CUT M
OPEN CUT 5
CUT X
DRIFT I
DRIFT G
Open cuts
DRIFT A2
DRIFT E
DRIFT D
25' level
DRIFT B
DRIFT A
DRIFT H (supposed)
Shaft
96' level
SECTION
Scale 50 0 50 100 Feet
GEOLOGIC MAP
AMMONS VERMICULITE MINE
MACON COUNTY, NC
N C DEPARTMENT OF CONSERVATION & DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT
KNOXVILLE 3-7-42 W CO I 821G7 RO

An interesting new development by the operator of this property consists of some experimental work on chlorite found there. Large crystals, definitely identified as that mineral, exfoliate at high temperatures and yield a light weight, tough, whitish product.

McGuire Property

This property is about ½ mile southwest of Ellijay Post Office and about 1,000 feet east of Ellijay Creek (see pl. 9). The vermiculite is associated with a very sound dunite mass about 1,000 feet long.

The vermiculite production from this property has been less than that of either the Ammons or the Angel. The most recent production has been from two drifts driven from the northern slope of a hill. A small quantity has been mined from open cuts near the crest of this hill. The vermiculite veins on this property seldom exceed 4 or 5 feet in width. Most of the veins trend east and west, perpendicular to the most common direction of those in the Ellijay district. The material from the McGuire property is pale green as contrasted with the brown material from the neighboring ones. This greenish vermiculite, upon exfoliation, weighs about 6 pounds per cubic foot, which is much below the average for the Ellijay district. The contacts have not been explored extensively; this should be done, especially on the southeast side.

Bud Mincey Mine

This property, opened as a corundum operation about 1900, is on the south side of Berry Prong of Ellijay Creek and about 800 feet east of Ellijay Post Office. The principal workings then consisted of a 125-foot shaft, a 122-foot drift, and several open cuts. All of these workings encountered vermiculite. In 1941 Minerals, Incorporated, began producing vermiculite from the property; in 1944 a new shaft was sunk in the bottom of the large open cut to prospect old corundum showings.

The principal vermiculite production has been from a new open cut about midway between the old corundum shaft and the creek, which followed a persistent, clean vermiculite vein. The walls of the cut are relatively sound dunite, which occassionally had to be held in place by stulls. This vermiculite vein ranges from 18 inches to a maximum of 10 feet in width; some parts of it have been worked to a depth of 40 feet. To date, the vermiculite production of this mine has consisted of a relatively small flake variety, best suited for plaster or concrete use. The property holds promise of becoming a producer of some importance, especially when the contacts are explored.

Ellijay Creek Prospect

This prospect is about ½ mile northwest of Ellijay Post Office and 2,000 feet west of Ellijay Church, on the bank of Ellijay Creek just upstream from the mouth of Berry Prong.

This occurrence is in one of the smallest masses of dunite in the Ellijay district. The mass has a length of about 500 feet and a maximum width of approximately 200 feet. Its crest lies about 40 feet above Ellijay Creek.

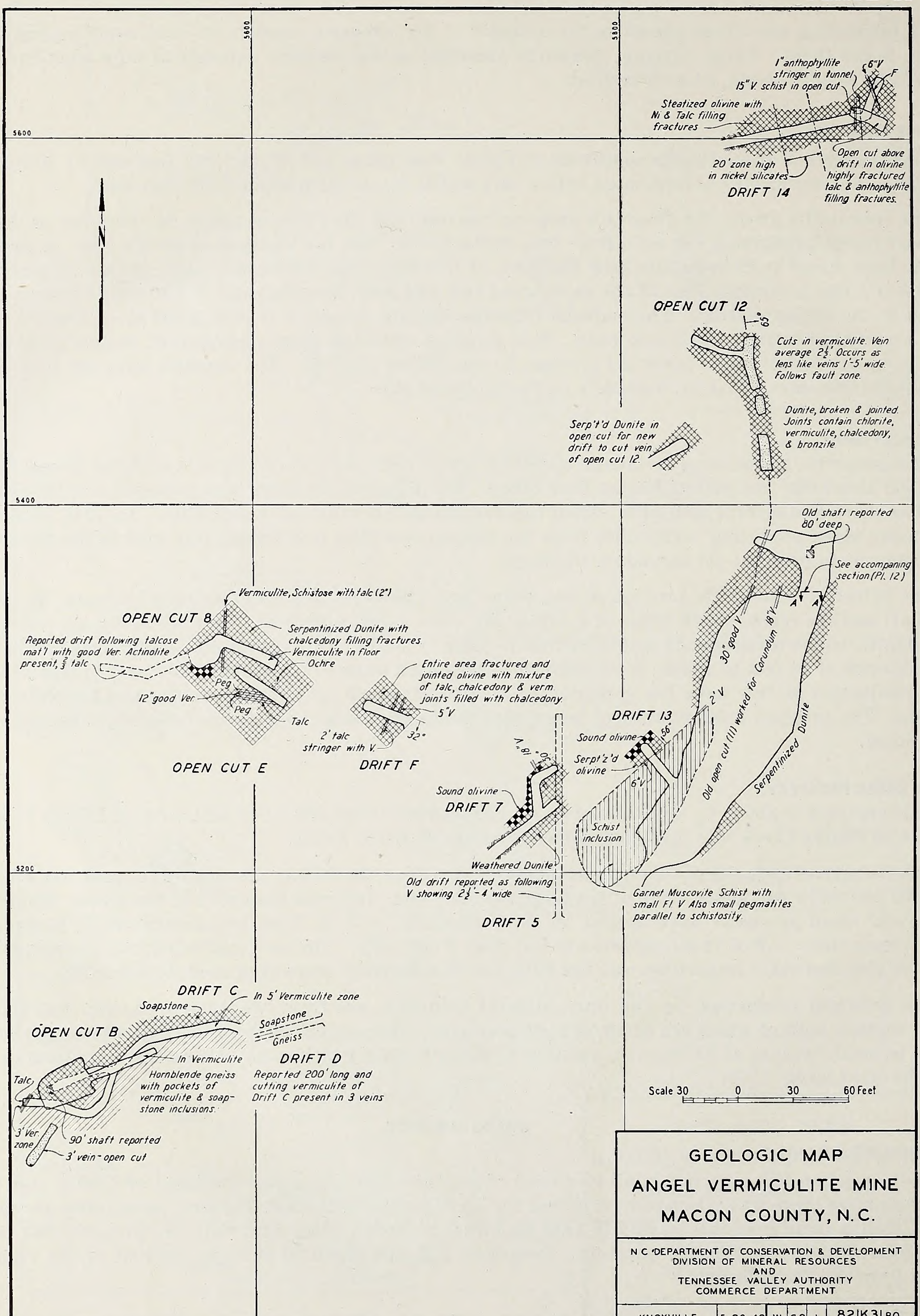
Several small prospects have opened up the formation; most of these encountered small pockets of excellent vermiculite. All of these pockets are less than 3 feet wide. The vermiculite is brown in color, relatively free from clay and other impurities, and the flake size is sufficiently large to be used for house fill.

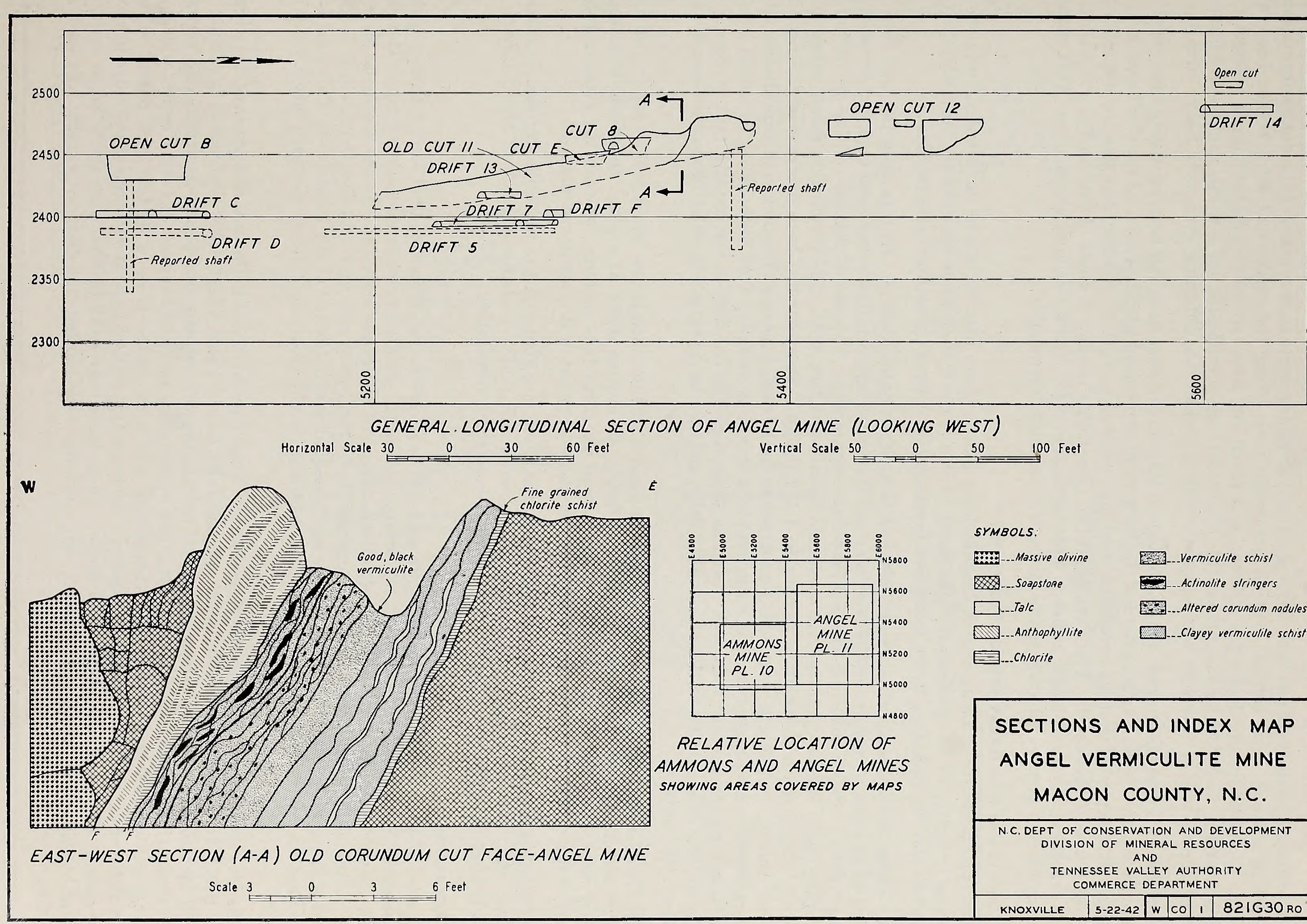
The principal production, by the Cary Mineral Company, was from two small open cuts, near the northeastern contact, both of which are about 30 to 60 feet long. The production from this deposit would necessarily have to be small because of its location, adjacent to Ellijay Creek, which would cause a water problem in mining below the creek level.

GNEISS DISTRICT

Corundum Hill Deposit

The Corundum Hill mine is 6 miles southeast of Franklin and 1-¼ miles northeast of Gneiss (see pl. 13). The dunite mass there was extensively exploited for corundum prior to 1910. The first vermiculite production in North Carolina came from this locality in 1933, by Philip S. Hoyt. Since that date the property has been exploited intermittently by various operators. Corundum Hill has produced perhaps one-half of the vermiculite shipped from the Franklin area.


5600
5800
5400
5200
N
1" anthophyllite stringer in tunnel
15" V. schist in open cut
6"V
F
Steatized olivine with Ni & Talc filling fractures
Open cut above drift in olivine highly fractured talc & anthophyllite filling fractures.
20' zone high in nickel silicates
DRIFT 14
OPEN CUT 12
Cuts in vermiculite. Vein average 2½'. Occurs as lens like veins 1'-5' wide. Follows fault zone.
Dunite, broken & jointed. Joints contain chlorite, vermiculite, chalcedony, & bronzite
Serp't'd Dunite in open cut for new drift to cut vein of open cut 12.
Old shaft reported 80' deep
See accompaning section (Pl. 12)
30" good V
18"V
2'V
Old open cut (11) worked for Corundum
Serpentinized Dunite
Vermiculite, Schistose with talc (2")
OPEN CUT 8
Reported drift following talcose mat'l with good Ver. Actinolite present, ⅔ talc
Serpentinized Dunite with chalcedony filling fractures
Vermiculite in floor
Ochre
Peg
12" good Ver.
Talc
OPEN CUT E
Entire area fractured and jointed olivine with mixture of talc, chalcedony & verm. joints filled with chalcedony
5"V
32°
2' talc stringer with V.
DRIFT F
DRIFT 13
Sound olivine
Serpt'z'd olivine
6"V
Schist inclusion
Sound olivine
DRIFT 7
Weathered Dunite
Old drift reported as following V showing 2½'-4' wide
DRIFT 5
Garnet Muscovite Schist with small Fl. V. Also small pegmatites parallel to schistosity.
DRIFT C
Soapstone
In 5' Vermiculite zone
OPEN CUT B
Soapstone
Gneiss
In Vermiculite
Hornblende gneiss with pockets of vermiculite & soapstone inclusions.
DRIFT D
Reported 200' long and cutting vermiculite of Drift C present in 3 veins
Talc
3' Ver. zone
90' shaft reported
3' vein - open cut
Scale 30 0 30 60 Feet
GEOLOGIC MAP
ANGEL VERMICULITE MINE
MACON COUNTY, N.C.
N C DEPARTMENT OF CONSERVATION & DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT
KNOXVILLE 5-26-42 W CO 1 821K31 RO


2500
2450
2400
2350
2300
5200
5400
5600
N
OPEN CUT B
DRIFT C
DRIFT D
Reported shaft
OLD CUT 11
DRIFT 13
CUT E
CUT 8
DRIFT 7
DRIFT F
DRIFT 5
A
A
Reported shaft
OPEN CUT 12
Open cut
DRIFT 14
GENERAL LONGITUDINAL SECTION OF ANGEL MINE (LOOKING WEST)
Horizontal Scale 30 0 30 60 Feet
Vertical Scale 50 0 50 100 Feet
W
E
Fine grained chlorite schist
Good, black vermiculite
F
F
EAST-WEST SECTION (A-A) OLD CORUNDUM CUT FACE-ANGEL MINE
Scale 3 0 3 6 Feet
E4800
E5000
E5200
E5400
E5600
E5800
E6000
N5800
N5600
N5400
N5200
N5000
N4800
AMMONS MINE PL. 10
ANGEL MINE PL. 11
RELATIVE LOCATION OF AMMONS AND ANGEL MINES
SHOWING AREAS COVERED BY MAPS
SYMBOLS:
Massive olivine
Soapstone
Talc
Anthophyllite
Chlorite
Vermiculite schist
Actinolite stringers
Altered corundum nodules
Clayey vermiculite schist
SECTIONS AND INDEX MAP
ANGEL VERMICULITE MINE
MACON COUNTY, N.C.
N.C. DEPT OF CONSERVATION AND DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT
KNOXVILLE
5-22-42
W
CO
I
821G30 RO

The principal production has been from open cuts along the northwest contact of the dunite formation with the enclosing gneiss. This contact vein is persistent both along the strike and dip. It has been worked around the periphery of the dunite for a distance of about 400 feet. At several places mining reached a maximum depth of 100 feet. At two points on this vein the clean vermiculite has a width slightly in excess of 20 feet. The dunite wall of this vein was supported with considerable difficulty, even with heavy square sets.

There are two important areas at the Corundum Hill deposit that have not been prospected for vermiculite. These are the northeastern contact zone and the border of the mica schist inclusion near the northwest side of the formation. It is reported that old corundum workings reached a depth of 300 feet and that good-quality vermiculite was found at this depth. The Corundum Hill vermiculite usually consists of extremely large flakes, many of which reach a diameter of 5 or 6 inches, a most unusual size for North Carolina vermiculite. This material is said to require a higher exfoliation temperature than average vermiculite.

SALEM SCHOOL AND PINE GROVE SCHOOL PROSPECTS

These prospects are in a long dike of amphibolized dunite which may be traced for 2 miles, from the headwaters of a tributary of Crows Branch to the south border of the Corbin Knob Quadrangle (167-NE); it crosses Highway 64 and the Cullasaja River 1,000 feet northwest of Walnut Creek Road (see pl. 13).

The Salem School prospect is about 1,600 feet N.23°E. of Salem School. At this point the host rock might be described as a dunite-soapstone-chlorite mass and the accessory vermiculite has been explored by several pits and an old drift. One of these pits exposes first-class vermiculite. The size of this pit and the amount of vermiculite in the dump indicate that the vein must have been 3 or 4 feet wide. The vermiculite flakes range in diameter from 1/16 inch for a schistose variety to 1-1/2 inches. The drift has been driven along the contact of the gneiss country rock on the west and the soapstone on the east, exposing an 8-inch vein immediately adjacent to the soapstone and separated from a 3-inch vein by a thin lens of talc. This vermiculite is second grade and the crystals range from 1/16 inch to 2 inches in diameter. The banding of the country rock strikes N.15°W. and dips 61°W.; it is parallel to the vermiculite veins and an 8-inch pegmatite which lies in the soapstone, about 6 feet from the contact.

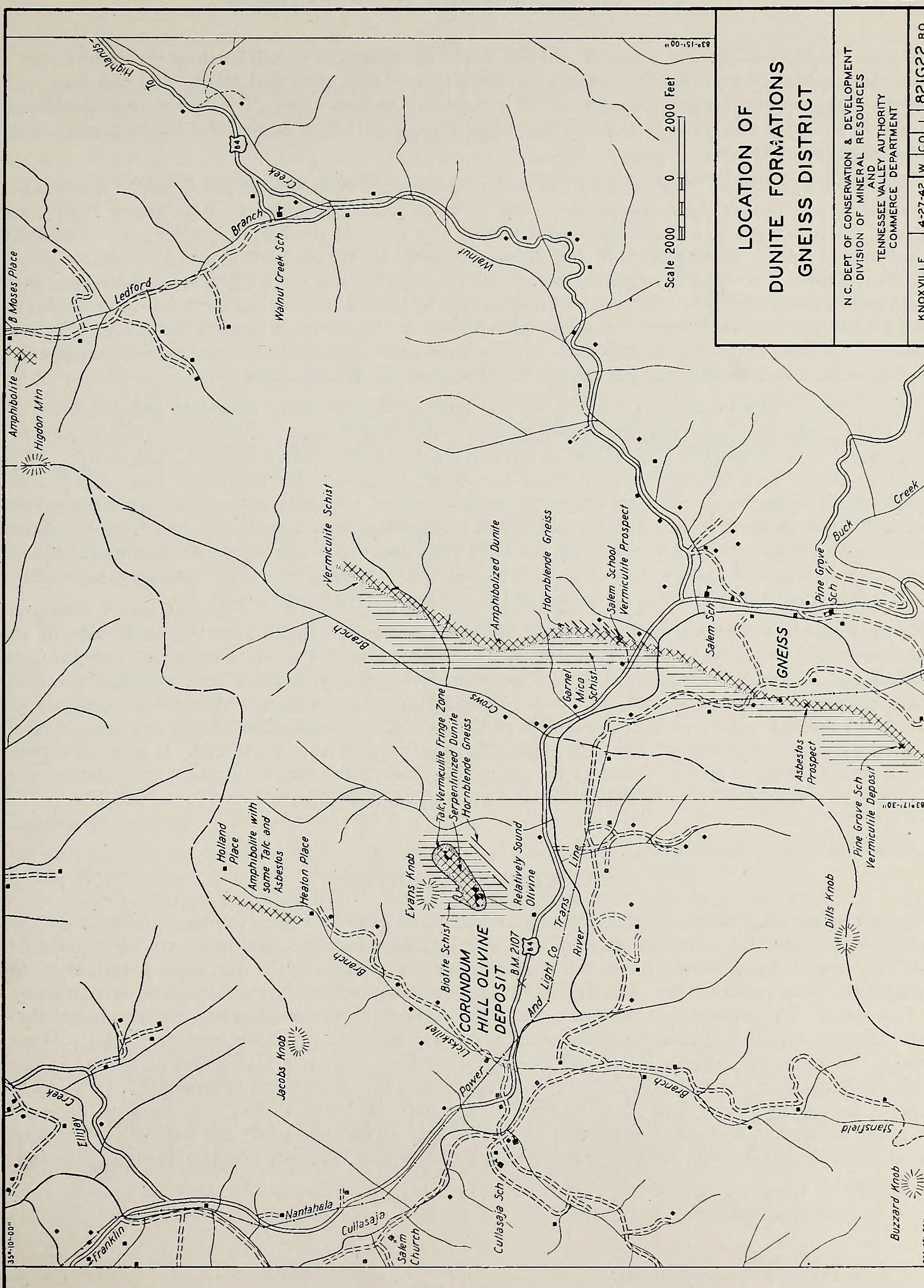
The Pine Grove School prospect is ½ mile southwest of the schoolhouse and ¾ mile east of Dill's Knob. The formation is exposed over a width of about 50 feet by an erosion gully, at a point about 300 feet west of a secondary road. Vermiculite is found in the dump of an old corundum opening, between the erosion gully and the road; some of the flakes are of 1-inch diameter, however most of it is schistose material.

Vermiculite float is observed at a number of points along the dike and the material in place is exposed in road cuts. Additional exploration is needed to determine the quality and the quantity of the material. It is possible that prospecting along the contacts will prove up some vermiculite.

OTHER LOCALITIES

Charles Mincey Place—A narrow dunite mass occurs 2,200 feet southeast of the Charles Mincey home and 1 mile south of Ellijay School (see pl. 9). A prospect pit in the dunite-gneiss contact on the top of the ridge to the west shows five ½-inch to 2-inch vermiculite stringers of low-grade material. To the northeast an interior zone of vermiculite strikes N.60°E. and is exposed by several open cuts and a 25-foot drift, along a distance of 180 feet from the crest of the ridge to the southwest, almost to the end of the formation. This zone is made up of several 5- to 10-inch veinlets, largely surrounded by chlorite, and follows a single large joint in the dunite.

Jake Henry Place—The above-mentioned dunite mass may be traced to the east and appears, together with another belt which extends from the south, on the Jake Henry Place about 4,000 feet north of Cedar Knob. About 50 feet north of a small stream, a contact zone of brown, resinous, fine-flake vermiculite and vermiculite schist is exposed, in contact with mica schist. The zone is made up of two veinlets, 12 and 8 inches wide. About 400 feet northwest of this exposure, anthophyllite has been mined from a 30-foot cut, 8 feet deep, and a 6-inch stringer of good vermiculite is exposed. Between this contact zone and the top of the ridge to the west, there are about 15 pits of variable size and shape. These have been sunk in what appears to be an inclusion of weathered biotite schist in the dunite mass. This material decrepitates, but does not exfoliate as does a true vermiculite.


LOCATION OF
DUNITE FORMATIONS
GNEISS DISTRICT
N.C. DEPT OF CONSERVATION & DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT
KNOXVILLE
4-27-42
W
CO
1
821G22
RO
Scale 2000
0
2000 Feet
83°-15'-00"
83°-17'-30"
35°-10'-00"
35°-07'-30"
To Highlands
84
Walnut Creek Branch
Walnut Creek Sch
Ledford
B Moses Place
Amphibolite
Higdon Mtn
Vermiculite Schist
Amphibolized Dunite
Hornblende Gneiss
Salem School Vermiculite Prospect
Branch
Crows
Garnet Mica Schist
Salem Sch
GNEISS
Pine Grove Sch
Buck Creek
Asbestos Prospect
Pine Grove Sch Vermiculite Deposit
Talc, Vermiculite Fringe Zone
Serpentinized Dunite
Hornblende Gneiss
Holland Place
Amphibolite with some Talc and Asbestos
Heaton Place
Evans Knob
Relatively Sound Olivine
Biotite Schist
CORUNDUM HILL OLIVINE DEPOSIT
B.M. 2107
Trans River Line
And Light Co.
Power
Dills Knob
Lickskillet Branch
Jacobs Knob
Ellijay Creek
Franklin
Nantahala
Cullasaja
Salem Church
Cullasaja Sch
Stansfield Branch
Buzzard Knob

Higdon Mountain—Several dikes of altered dunite occur around Rough Knob on the eastern part of Higdon Mountain (see pls. 9 and 13). These dikes average about 30 feet wide and 300 to 400 feet long. At many points along the contacts, much prospecting for corundum has been done. The dumps show vermiculite, but most of it is second grade. The formation is so badly fractured that is is doubtful if much good vermiculite could be taken from this area.

Vance Jennings Place—This prospect lies in the west-central rectangle of the Glenville Quadrangle (176-NW), about ½ mile east of the Angel property and the same distance south of Little Rocky Mountain. There are several drifts and pits in a soapstone mass about ¼ mile north of the Jennings home. The best showing of vermiculite is in a drift running N.16°W. for 30 feet, thence N.82°W. for 39 feet, and cutting a highly faulted contact zone made up essentially of gneiss, but with three fault blocks of talc exposed. Numerous small pegmatites have impregnated the fault zone and a series of veinlets and small pockets of vermiculite up to 2 inches in width cut the talc blocks. Very fine flake disseminated vermiculite constitutes about 5 percent of the gneiss. All the vermiculite in this drift is of a good grade. The other openings show only small vermiculite exposures. The commercial possibilities of this property appear doubtful.

Adams Place—This prospect is about 2,300 feet north of Little Rocky Mountain and just west of Little Salt Rock Cove, near the northwestern border of the Glenville Quadrangle (176-NW). A lens of altered dunite is found there; it has a length of 1,900 feet in a north-south direction and the width ranges from 400 feet in the center to 200 feet on the ends. The country rock is biotite schist; the dunite has been highly steatitized and is accompanied by highly crinkled and folded schistose talc. The north contact has been partly explored by a short drift which exposes 18 inches of low grade, clayey vermiculite at a point six feet from the mouth; the drift is caved but apparently runs south for about 18 feet, and exposes boulders of decomposed olivine with narrow 1-inch stringers of vermiculite surrounded by anthophyllite. Several other openings expose minor showings, but on the whole the property does not appear to merit extensive prospecting.

Norton Property—The Norton dunite occurs 14 miles south of Franklin, on the north side of Commissioners Creek and 1 miles west of the Tullulah Falls Railroad. There are seven vermiculite prospect pits along the east contact. Six of these expose only a weathered biotite, stained a golden brown, and the seventh cuts a 6-inch vein of vermiculite-like material, with a large pegmatite as the hanging wall and weathered soapstone as the footwall. A small quartz vein, in the middle of this material, indicates that it was probably originally biotite around quartz and was formed when the pegmatite came up, and later weathered. It is possible that vermiculite in some quantity might be found at this property. The dunite mass contains a little olivine; it is composed mostly of anthophyllite and chlorite, which in places might have weathered to vermiculite.

MADISON COUNTY

The belt of peridotites that passes through Democrat, Buncombe County, crosses the extreme corner of Madison County. The Holcombe Branch dunite mass is 1½ miles north of Democrat, on both sides of Holcomb Branch. Hunter[41], describes the formation as very irregular in outline; the maximum length and width are 3,000 and 1,500 feet, respectively. The formation is somewhat broken up by faults and it contains several schist inclusions. While the occurrences of commercial vermiculite is not indicated, the presence of chlorite in joints is definitely known and some vermiculite may be found along the contacts and particularly along those adjacent to the schist inclusions. Pratt and Lewis[42] report that corundum was mined at the old Carter mine on Holcombe Branch; it was found in an interior vein, enclosed by chlorite and vermiculite. Two and one-half miles northeast of the Carter mine, 2 miles above the mouth of Terry Creek, is a massive, dark green to almost black serpentine with some soapstone and chlorite in an outcrop about 200 feet. Peridotites occur in several other parts of Madison County, but there is no particular reason to consider them as potential vermiculite prospects.

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[41] Hunter, C. E., op. cit., p. 58.
[42] Pratt, J. H., and Lewis, J. V., op. cit., p. 258.

MITCHELL COUNTY

There are numerous outcrops of peridotite and enstatite rocks in this county, but reports indicate very little associated vermiculite. The Bakersville dunite mass, on White Oak Creek 1 mile southeast of Bakersville, has been described by Hunter.[43] Overburden obscures a part of the formation, but it appears to be about 300 feet long and 60 feet wide. The most unique feature of this deposit is the presence of chrysotile asbestos as seams up to 6 inches thick and as individual fibers and clusters of fibers penetrating individual olivine grains.

Bear Creek

The vermiculite-like material on the Pipkins property, at the headwaters of Little Bear Creek and approximately ½ mile west of Little Bald Mountain (209NE), constitutes a unique occurrence. An open cut runs S. 68°E. into a pegmatite for 50 feet and then turns to the southwest for 30 feet. The vermiculite-like material, which is 3 feet thick with extensions running downward at right angles, strikes N.16°E. and dips 28°W. Blocks of intergrown crystals 2 feet or more in diameter can be found in the sides of the cut. Faulting is quite pronounced throughout the entire exposure and the seam ends with a fault plane. The entire pegmatite has been injected into a hornblende gneiss although the capping at the cut entrance is a garnet-biotite schist. The material varies in color from black to light golden and grades from a hard, "harsh" biotite into a smooth, soft vermiculite-like mineral. The occurrence is as books, intergrown into the pegmatite with feldspar around the individual books.

One-fourth mile S.32°W. of this opening, on the Pitman Property, another cut runs S.30°E. for about 100 feet into the side of the mountain, and reaches a depth of about 25 feet. Feldspar is the principal mineral exposed and is highly kaolinized. In the southeast end of the cut a vermiculite-like material, somewhat similar to that found at the other opening, is exposed.

These occurrences are the only ones seen in the field which even suggest that biotite might have been the ancestor of vermiculite; this is not conclusive since the material could hardly be classed as a true vermiculite. It is not, however, the usual biotite or iron-stained muscovite, since upon heating it does not merely delaminate, but really exfoliates. Field tests indicated this to be the case and laboratory tests showed a sample from the Pitman property to be one of the best. The only explanation lies in the fact that faulting in the area has provided ready access for what might be called "vermiculizing" solutions from a nearby altered peridotite which is known to occur.

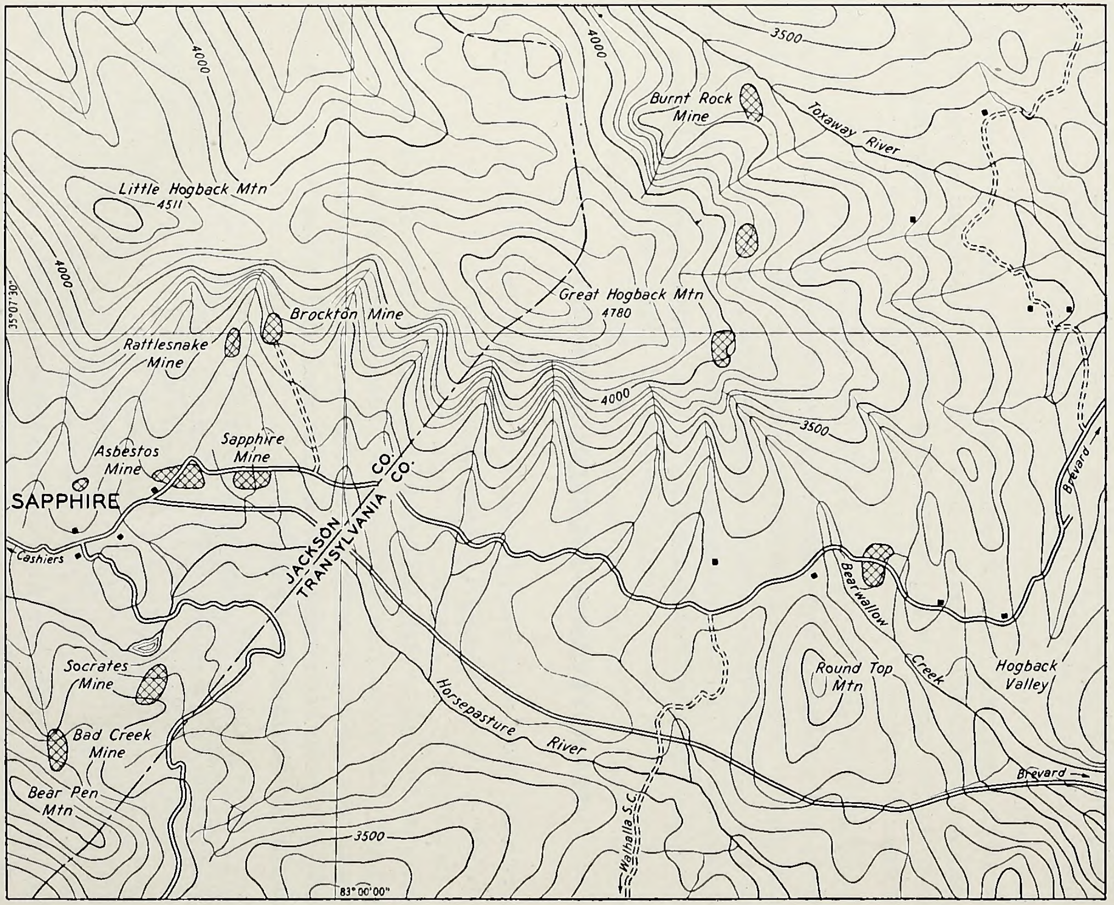
TRANSYLVANIA-JACKSON COUNTIES

Canada-Sapphire District

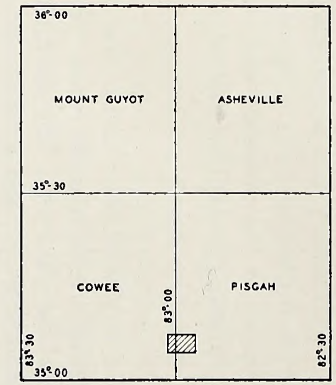
This district is in the southeast part of Jackson County and adjacent Transylvania County east of Sapphire and between Horsepasture River on the south and Toxaway River on the north (see pl. 14). There has been practically no vermiculite exploitation in the district, although it was once an important center of corundum mining. The Canada area lies near the headwaters of Tuckasegee River (East Fork), on partially improved State Highway 281, approximately 12 miles from Tuckasegee. The Sapphire area is adjacent to Highway 64, between Rosman and Cashiers. Both areas have been described in detail by Pratt and Lewis.[44] The 1941 field work there consisted only of a brief reconnaissance to visit localities where some activity had been reported and to study the general possibilities of the district.

In the northwest rectangle of the Lake Toxaway Quadrangle (185-NW) about 3,000 feet south of Wolf Creek Church, several vermiculite zones are exposed in a folded dunite dike. One of these, in the road cut 300 feet east of Wolf Creek Post Office, consists of a 2½-foot contact vein of low grade, small flake, schistose material. Near a small graveyard, a 15-foot contact zone of good grade vermiculite associated with talc is exposed, consisting of a 7-foot vein and two smaller ones. Most of the vermiculite is ¼ inch in diameter and considerable clay impurities are present, probably resulting from the weathering of near-by granite. This condition should not continue at depth. In this vicinity dunite and enstatalite (enstatite rock) occur in several places, particularly near the mouth of Tennessee Creek. At the old Whitewater mine, 5 miles southwest of Sapphire,

[43] Hunter, C. E., op. cit., p. 57.
[44] Pratt, J. H., and Lewis, J. V., op. cit. pp. 42-47; 252-256.



NOTE: After Pratt & Lewis (N. C. Geol. Survey Vol I, Plate VII)



INDEX MAP

USGS Quadrangles 1:125000

Scale 1000 0 1 2 3 4 5000 Feet

Contour interval 100 Ft

LOCATION OF PERIDOTITE AREAS – SAPPHIRE DISTRICT JACKSON – TRANSYLVANIA COS

N C DEPT OF CONSERVATION AND DEVELOPMENT
DIVISION OF MINERAL RESOURCES
AND
TENNESSEE VALLEY AUTHORITY
COMMERCE DEPARTMENT

KNOXVILLE	4-30-42	W	CO	I	821G24 RO

in an oval outcrop of peridotite about 100 feet wide, fine scaly vermiculite occures along the joints and in contacts with gneiss. Soapstone, probably representing similar rocks, occurs on the southern slopes of Terrapin Mountain, 2 miles west of the Whitewater mine. A small mass of peridotite is reported on the north end of Whiteside Mountain, near Devils Courthouse.

The accompanying map (pl. 14) shows the distribution of peridotites near Sapphire. Vermiculite was encountered in association with corundum in many of these peridotites. The most southerly outcrop is at the old Bad Creek mine, 1 mile south of Sapphire. Here a lenticular mass, 50 by 200 feet, consists chiefly of enstatalite, but in places passes into dunite. The old Socrates mine is located ½ mile northeast of the Bad Creek, where a lens of enstatalite, about 250 by 900 feet, occurs. At the northeast end of the outcrop the gneiss dips 40° SE., under the pyroxenite. One or two feet of the gneiss at the contact are thickly impregnated with a fine, scaly vermiculite. Between this and the pyroxenite is a sheet of similar vermiculite about 4 inches thick with a few inches of pulverant and scaly talc, and some chlorite next to the pyroxenite.

Corundum was produced from these old mines and asbestos as well, from the Rattlesnake, Brockton, Sapphire and Burnt Rock. The latter property is on Highway 64 and a large amount of vermiculite is to be seen in the old dump and in the caved mouth of the old portal. At the Brockton mine vermiculite gangue was rather widespread in the early corundum mining. Other localities in this area where peridotite rocks occur include: southeast of Great Hogback Mountain; 3 or 4 miles east of Sapphire, where several dunite masses occur; about 15 miles northeast of Great Hogback Mountain, where a dozen small outcrops of saxonite and enstatalite are found; 1 mile east of Buck Mountain and 4 miles due south of Sapphire where a mass of dunite 150 feet wide outcrops in a road cut; and, 5 miles northwest of Sapphire and ½ mile north of Sheep Cliff Mountain, where large outcrops of dunite occur. It is probable that carefully planned prospecting in these areas would locate a considerable tonnage of vermiculite. In many cases, however, the location would not be readily accessible and delivery to main highways would be costly.

UPPER WOLF CREEK

Some exploration for vermiculite, consisting of three shallow pits sunk in a biotite schist member of the Carolina gneiss, is noted on Wolf Creek, 3,000 feet above the mouth of Cold Creek, and ¾ mile northeast of Charley Knob, in the southwest rectangle of the Sam Knob Quadrangle (164-SW). Due to the entire absence of any basic rocks in this vicinity, the vermiculite-like material exposed can hardly be considered as a true vermiculite, although it does bear a certain resemblance.

YANCEY COUNTY

While there has been no development for vermiculite in Yancey County, the possibility of the existence of commercial vermiculite is suggested by the occurrence of several large peridotite masses and the active operation of an olivine quarry. The Toecane area, about 12 miles long and 8 miles wide, is about 30 miles northeast of Asheville and extends from the center of Yancey County to a short distance beyond Bakersville. This area is described by Hunter[45] as being characterized by fine-grained dunites and saxonites that have a distinctive yellow color on the weathered surface.

The largest and most outstanding peridotite in the Toecane area is at Day Book, about 3 miles north of Burnsville, on Mine Fork of Jack's Creek. This deposit is about 2,000 feet long and 600 feet wide and outcrops as hills on both sides of Mine Fork. Much of the outer portion hes been altered by hydrothermal solutions, while the relatively unaltered material occurs as a lens-shaped zone near the center of the formation. Near the faults and larger joints in the deposit the olivine shows signs of chloritization. An interior vermiculite zone, exposed on the west side of the quarry operated there, is 2 to 3 feet wide. Anthophyllite is exposed along the northwest contact. The vermiculite is schistose, of a resinous luster; it breaks down into very fine flakes and is accompanied by talc and actinolite. Some vermiculite is also exposed on the east side of the quarry but it is less pronounced than on the west. The southwest contact offers the possibility of vermiculite, more so than does the northwest one where the dunite is in contact with a granite mass.

[45] Hunter, C. E., op. cit., p. 48.

APPENDIX

COMPILATION OF DATA OF VERMICULITE EXFOLIATION TESTS AND CHEMICAL ANALYSES

Thirty samples of vermiculite, taken from western North Carolina deposits by the field geologists during the survey, were sent to the Authority's Minerals Testing Laboratory at Norris, Tennessee. The tests were conducted by Mr. F. A. W. Davis, who had carried out previous research on vermiculite.[46] In this Appendix is given a description of the procedure used and observations made as a result of the tests. The locations from which the samples were taken, the results of the screen analyses and exfoliation tests, and chemical analyses are given in tabular form following the subject matter.

PROCEDURE

After prolonged air drying, the crude samples were quartered down for mechanical analyses. Material from each crude sample was sized by screening. Mechanical analyses were run on all the crude sizings exfoliated. These analyses serve to indicate the degree of disintegration of the various sizings during exfoliation.

Apparent Density of Crude Ore

The apparent density of each crude sizing was determined by placing a pasteboard carton, having a capacity of 482 cubic centimeters, in a sieve pan mounted on the electric vibrator. This carton was filled with sized material, adding additional sizings from time to time until vibrated to refusal, that is, until constant volume is obtained. The material in the carton was then weighed in grams and converted to pounds per cubic foot.

Exfoliation

For exfoliation a Hoskins electric muffle furnace was heated to its maximum temperature (900° C.). A portion of one sizing was then spread thinly over the bottom of a sheet iron pan made to fit easily within the muffle. The pan, which was attached to a long flat iron handle, was slid rapidly into the muffle and the door of the furnace closed. The temperature leveled off, ranging from 640° to 740° C. during each charging. Charging of the pan was repeated until the entire amount of the sizing contained in the carton has been through the furnace.

The correct time period for complete exfoliation was determined. In most of the sizings the time period for exfoliation varied from 30 to 45 seconds; however, some required only 20 seconds while others required at least 60 seconds.

Apparent Density of Exfoliated Vermiculite

During the heating process the material expands or exfoliates, thereby changing the apparent density. All of the expanded material derived from a carton of crude sizing was vibrated to constant volume, using the same carton. The apparent density of that particular sizing in grams per cubic centimeter was converted to pounds per cubic foot. Furthermore, the enlarged volume, divided by the original volume of the crude sizing in the carton, gives the actual number of times the original volume had increased due to exfoliation.

OBSERVATIONS

Impurities noted were talc, serpentine, feldspar, silica, clay, and iron oxide. Some of the sizings contained sufficient gangue to more or less smother the exfoliation of the good vermiculite. Extremely weathered crude vermiculite exfoliates very little. The presence of impurities or any vermiculite which does not exfoliate, although not in sufficient quantities to hinder exfoliation, increases the apparent density after exfoliation. The

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[46] Davis, F. A. W., and Johnson, M., Research work on North Carolina vermiculite: Tennessee Valley Auth. Div. Geology Bull. 5, pp. 11-21, December 1936.

minus 60 crude ore should be wasted as too high in clay, iron oxide, and fine gangue materials. To get the lowest apparent density after exfoliation, removal of the gangue either before, during, or after exfoliation would be necessary for about 60 percent of the crude samples tested.

Tests on the platy type of ore indicated better bulking values than the so-called lump type. The lump type is probably derived from books of the platy type irregularly weathered around the edges. During exfoliation the smaller cross-sections of each lump are detached from it, causing disintegration.

It was not possible to exfoliate at temperatures above 740° C. with the equipment and method used. It might be possible, however, that temperatures up to 900° C. might increase the degree of exfoliation somewhat in some of the samples.

Of the crude sizings, 60 percent had less than 60 percent of the particles retained on plus 10 mesh, which is a low yield for "Housefill." Care in processing the crude material is very important in order to cut down on the finer sizes. Crude ore as it comes from the mine should be gently dried at 110° C. and then fed to a vibrating screen to take out the minus ½ mesh. The oversize should then be accumulated and disintegrated to yield as much minus ½ plus 4, minus 4 plus 10 mesh as possible.

All the exfoliated material was found to be quite friable and would break down unless handled carefully. It is necessary therefore to cut down on the number of times the exfoliated material is handled, both in processing and when used, especially the minus ½ plus 4 and minus 4 plus 10 mesh in "Housefill."

It would seem this disintegration due to handling might be obviated by transporting the sized crude ore to the site of the job and exfoliating it there. A portable furnace for the proper exfoliation of the material would have to be designed. Yield could also be increased if some method could be found for forming the finer exfoliated material into clusters, and strengthening the particles, thereby permitting them also to be used as housefill.

SAMPLES TESTED

Below is an identification of the samples listed in Tables I and II.

Sample No.	*Location*	*Description*
1	Addie No. 1 (Ocher Creek)	Taken over a 20-foot zone about 400 feet from branch.
2	Addie No. 2 (Ocher Creek)	From zone similar to Sample No. 1, located 180 feet to the northwest.
3	Addie No. 3 (Ocher Creek)	From southwest contact vein.
4	Addie No. 4 (Ocher Creek)	Composite of two five-foot zones of good vermiculite and a two-foot zone of schistose material, occurring just north of the intersection of Ocher Creek road with the east-west one.
5	Addie No. 5 (Fisher)	Composite of clayey material exposed in two pits south of the propect trench.
6	Addie No. 6 (Fisher)	From exposure of higher grade material at the end of the trench.
7	Addie No. 7 (Fisher)	Composite of lower grade material cut 100 feet to the northwest by the trench and of two test pits to the east.
8	Ammons Mine	Run-of-mine vermiculite from screening plant bin.
9	Angel Property	From material being mined from open cut 12.
10	Angel Tunnel No. 13	Schist bearing small flakes of vermiculite as exposed in drift 13.
11	Bear Creek No. 1	From Pipkins Place.
12	Bear Creek No. 2	From Pitman Place.
13	Cane Creek No. 1	Composite of different vermiculite zones exposed in a test trench northwest of the Hooper home.
14	Cane Creek No. 2	Composite containing 80 percent from test pit north of Hooper home and remainder from outcrops in that area and at the base of the hill.
15	Coggins No. 1 Bee Tree	Run-of-mine material from No. 1 pit.
16	Coggins No. 2	Stock-pile of heavy white-centered material from No. 3 pit.
17	Cowards Property	From pit at Cowards prospect.
18	Cowarts No. 1	Largest size of screened vermiculite shipped from the plant at Cowarts.
19	Cowarts No. 2	Smallest size of screened vermiculite shipped from the plant at Cowarts.
20	Cowarts No. 3	Run-of -mine material from the crude bin at Cowarts.

Sample No.	*Location*	*Description*
21	Day Book	Vermiculite exposed west of Day Book olivine quarry.
22	Ellijay Creek	Of sacked material piled near the old workings at the property.
23	Lake Summit No. 1	Micaceous material occurring with the kaolinized feldspar at the exposure 200 feet vertically above the lake.
24	Lake Summit No. 2	Small flake material occuring with the biotite schist adjacent to the granite near the lake shore.
25	Lovedohol Property	From stock-pile.
26	McGuire Property	Taken from some sacked material piled near the principal underground workings.
27	Bud Mincey Mine	Vermiculite being extracted from the main trench.
28	Anderson Place—Shooting Creek	From five-foot zone of exposed vermiculite-like schistose material.
29	Rogers Place—Shooting Creek	Standard sample from the most northeastern pit.
30	Wolf Creek	Taken by cross-sectioning the principal exposure.

TABLE I

SCREEN ANALYSES OF CRUDE AND EXFOLIATED VERMICULITE ORE

U. S. Series Sieve Numbers

Sample No.	Crude Ore									Exfoliated Ore								
	Cumulative Percent Retained On									Crude Sizing—4+10			Crude Sizing—10+30			Crude Sizing—30+60		
	1-½″	1″	¾″	½″	4	10	30	60	−60	% 1+4	%−4 +10	% −10	% +10	%−10 +30	% −30	% +30	%−30 +60	% −60
1	......	......	......	20.61	44.41	62.57	85.87	94.38	5.62	17.5	56.5	26.0	15.0	78.8	6.2	26.5	69.5	4.0
2	......	......	......	24.95	37.95	52.05	78.32	91.53	8.47	3.4	60.4	36.2	8.4	78.9	12.7	13.9	74.0	12.1
3	......	......	......	10.82	34.47	55.68	77.88	89.40	10.60	18.6	58.1	23.3	16.5	72.9	10.6	11.6	78.4	10.0
4	......	......	......	16.10	45.25	63.60	85.10	93.99	6.01	16.9	59.1	24.0	17.0	73.8	9.2	15.1	77.5	7.4
5	......	......	......	13.60	30.48	44.95	71.85	88.71	11.29	15.2	44.1	40.7	11.7	74.1	14.2	13.6	70.8	15.6
6	......	......	......	28.75	56.30	72.50	87.99	94.50	5.50	25.5	41.6	32.9	36.8	56.4	6.8	16.2	77.0	6.8
7	......	......	......	32.95	52.77	67.06	84.01	92.36	7.64	22.5	58.1	19.4	14.7	69.5	15.8	11.9	74.7	13.4
8	......	......	......	4.94	14.27	35.46	72.84	88.55	11.45	25.5	46.2	28.3	39.2	60.0	0.7	54.6	42.1	4.3
9	......	......	......	13.83	39.47	58.96	83.53	93.85	6.15	27.0	49.1	23.9	17.2	69.5	13.3	20.4	62.4	17.2
10	......	......	......	......	3.94	12.08	23.50	64.60	35.40	......	......	......	1.2	65.6	32.8	6.0	87.8	6.2
11	45.00	54.57	62.52	69.59	83.83	89.76	96.03	98.31	1.69	16.5	66.6	16.9	9.6	77.4	13.0	18.7	73.7	7.6
12	63.80	74.20	80.56	85.07	93.95	96.86	98.78	99.50	.50	29.3	44.5	26.2	21.4	66.0	12.6	24.1	68.5	7.5
13	......	......	......	40.22	61.37	71.22	84.54	92.92	7.08	10.0	50.6	39.4	9.9	77.7	12.4	15.9	70.3	13.8
14	......	......	......	24.30	47.80	62.80	80.46	90.66	9.34	18.8	48.3	22.9	13.0	73.3	13.7	22.0	73.3	4.7
15	......	......	......	6.17	31.99	53.69	80.88	91.06	8.94	26.7	53.9	19.4	26.6	68.7	4.7	26.5	67.8	5.7
16	......	......	......	3.13	29.07	63.86	84.39	92.20	7.80	35.2	57.8	7.0	34.8	62.7	2.5	24.2	70.2	5.6
17	......	......	......	2.19	16.48	58.33	90.50	95.95	4.05	8.4	79.4	12.2	11.1	85.2	2.7	28.0	67.0	5.0
18	......	......	......	......	11.10	64.90	92.00	96.67	3.33	21.2	54.3	24.5	44.0	50.6	5.4	26.1	64.6	9.3
19	......	......	......	......	......	0.19	73.94	92.58	7.42	......	......	......	23.0	68.0	9.0	26.7	67.0	6.3
20	......	......	......	30.59	69.58	81.87	93.30	97.62	2.38	8.3	41.8	49.9	15.7	70.3	14.0	17.9	72.4	9.7
21	......	......	......	9.07	29.38	41.74	62.12	81.92	18.08	0.0	23.4	76.6	5.2	62.2	32.6	15.0	75.2	9.8
22	......	......	......	10.65	23.76	38.86	64.14	82.66	17.34	10.4	42.7	46.9	13.5	80.5	6.0	27.0	64.0	9.0
23	......	......	......	1.26	32.87	48.98	71.23	85.17	14.83	10.1	58.0	31.9	9.2	72.4	18.4	10.8	87.0	13.0
24	......	......	......	......	3.93	21.85	54.00	79.05	20.95	5.0	41.3	53.7	8.2	77.2	14.6	22.3	69.7	8.0
25	......	......	......	9.81	16.01	34.03	65.85	80.98	9.02	3.4	37.0	59.6	22.1	45.8	32.1	25.3	64.3	10.4
26	......	......	......	4.12	11.95	27.36	61.07	82.69	17.31	22.5	44.9	32.6	15.7	75.9	8.4	28.4	66.4	5.2
27	......	......	......	11.14	34.24	48.15	75.90	89.75	10.25	39.3	40.3	20.4	15.2	62.9	21.9	15.7	76.2	8.1
28	......	......	......	10.24	27.38	55.28	83.33	92.13	7.87	......	......	......	......	......	......	......	......	......
29	......	......	......	2.32	34.44	65.44	92.44	98.12	1.88	24.5	64.4	11.1	31.6	65.7	2.7	45.2	50.2	4.6
30	......	......	......	6.93	17.43	33.76	77.86	93.27	6.73	4.9	46.3	48.8	9.3	81.6	9.1	19.6	75.5	4.9

TABLE II

EXFOLIATION TESTS

Lab. No.	Location of Sample	Structure Types of Ore[1]	Visible Impurities[2]	Deg. of Weathering	Ave.[3] App. Den. of Crude Ore Lbs. per cu. ft.	−½+4 Size Lbs. per cu. ft.	−½+4 Size Vol Inc. Times	−4+10 Size Lbs per cu. ft.	−4+10 Size Vol. Inc. Times	−10+30 Size Lbs. per cu. ft.	−10+30 Size Vol. Inc. Times	−30+60 Size Lbs. per cu. ft.	−30+60 Size Vol. Inc. Times	Final Color
1	Addie No. 1 (Ocher Creek)	P & L	T or S*	Not weathered	70.24			15.66	4.73	23.15	2.96	28.80	2.00	Cream
2	Addie No. 2 (Ocher Creek)	L	T or S, C & Fe**	Not weathered	73.80			27.00	2.78	23.60	3.00	32.50	2.00	Cream
3	Addie No. 3 (Ocher Creek)	P	T. & C	Not weathered	71.40	11.43	4.66	13.10	5.57	19.16	3.31	26.41	2.04	Cream
4	Addie No. 4 (Ocher Creek)	P	T & C	Badly weathered	69.58	12.68	3.04	15.02	4.39	17.70	3.53	24.80	1.89	Cream
5	Addie No. 5 (Fisher)	L	Some gangue	Badly weathered	69.48	20.30	3.20	16.95	3.58	21.41	2.89	25.20	2.21	Brn & Crm
6	Addie No. 6 (Fisher)	P	T or S	Slightly weathered	66.24	7.25	8.50	9.88	6.41	14.10	4.30	25.20	1.68	Cream
7	Addie No. 7 (Fisher)	P	Some gangue	Slightly weathered	66.20	13.41	4.59	12.39	4.85	18.00	3.83	26.05	2.08	Brn & Crm
8	Ammons Mine	P	C & Fe	Not weathered	72.46			8.30	8.06	9.28	7.35	12.97	4.58	Brown
9	Angel Property	P	Some gangue	Not weathered	73.86	11.61	6.28	9.37	6.95	12.45	5.12	20.30	3.13	Brown
10	Angel Tunnel No. 13	P	High% gangue	Not weathered	69.06					39.80	1.63	36.60	1.84	Brown
11	Bear Creek No. 1	P	C & Fe—Some gangue	Not weathered	59.80	15.15	3.93	16.34	3.50	18.59	2.96	24.10	2.00	Brown
12	Bear Creek No. 2	P	C & Fe*	Not weathered	64.12	10.29	5.50	11.29	5.56	13.50	4.53	14.85	2.93	Brown
13	Cane Crook No. 1	L	C & Fe*	Badly weathered	73.76			20.21	3.06	20.92	2.96	26.92	1.96	Brown
14	Cane Creek No. 2	P	T	Not weathered	66.38	10.50	5.90	11.10	5.35	16.05	3.69	15.30	3.70	Cream
15	Coggins No. 1 Bee Tree	P & L	Q, C & Fe*	Not weathered	70.44	12.11	5.66	11.65	5.70	14.50	4.54	28.90	2.82	Brown
16	Coggins No. 2	P	C & Fe*	Not weathered	67.38	15.18	4.60	14.45	4.54	17.00	4.35	27.40	2.12	Brown
17	Cowards Property	P	C & Fe**	Not weathered	76.64	28.30	2.73	42.60	1.97	45.10	1.77	39.70	1.64	Brown
18	Cowarts No. 1	L	C & Fe*	Not weathered	64.24			13.35	4.75	13.42	4.50	17.25	1.96	Brown
19	Cowarts No. 2	L	C & Fe*	Not weathered	56.73					13.08	4.70	18.05	2.89	Brown
20	Cowarts No. 3	L	C & Fe*	Not weathered	65.92			12.30	5.04	13.25	6.66	16.68	3.18	Brown
21	Daybook	P		Not weathered	65.56	15.16	4.30	12.26	4.45	14.19	3.73	21.17	2.46	Brown
22	Ellijay Creek	L	T or S	Not weathered	75.64			12.20	6.15	29.68	3.80	23.60	3.96	Cream
23	Lake Summit No. 1	L	C & Fe**	Badly weathered	56.18	23.60	2.12	22.98	2.08	23.10	2.12	25.02	1.96	Brown
24	Lake Summit No. 2	L	C & Fe*	Badly weathered	70.36			17.39	3.42	16.70	3.93	20.10	2.77	Brown
25	Lovedohl Property	L	T, C & Fe	Not weathered	75.58			16.12	4.81	16.20	4.38	23.81	2.79	Brown
26	McGuire Property	P & L	T	Not weathered	68.08			10.80	5.46	13.15	4.44	18.55	2.96	Cream
27	Mincey Mine	P & L		Not weathered	67.12	9.10	6.73	9.78	5.88	15.05	4.06	19.30	2.69	Buff
28	Anderson Place—Shooting Creek	L	C & Fe**	Extremely weathered	46.16	All sizings do not exfoliate								
29	Rogers Place—Shooting Creek	P	C & Fe*	Not weathered	63.40	13.45	4.47	12.00	4.61	11.95	4.55	13.15	3.93	Brown
30	Wolf Creek	L	C & Fe*	Not weathered	73.96			15.30	4.67	14.87	4.69	22.60	2.60	Brown

[1] P-Platy; L-Lump; P-L-Platy-Lump.
[2] T-Talc; S-Serpentine; F-Feldspar; Q-Quartz; C-Clay; Fe-Iron Oxide; *-Low in Clay and Oxide Binder; **-High in Clay and Iron Oxide Binder.
[3] Arithmetical average of density of different sizings of crude ore.

TABLE III

Chemical Composition[47]

Sample No.	SiO_2	Al^2O^3	Fe_2O_3	MgO	K^2O	Na^2O	Ignition Loss	Total
1	37.40	11.69	2.61	24.24	...	...	24.40	100.34
2	33.58	22.80	4.98	21.44	...	...	18.00	100.80
3	37.04	10.53	4.96	28.95	...	...	17.60	99.08
4	36.40	22.68	7.12	15.70	...	...	18.40	100.30
5	35.80	16.13	14.75	11.73	...	...	18.55	96.96
6	36.01	9.42	4.64	29.83	...	...	19.55	99.45
7	34.10	12.24	6.46	29.00	...	...	18.60	100.40
8	34.70	11.16	12.34	22.03	2.48	4.08	13.18	99.97
9	33.00	15.44	13.36	23.97	...	...	15.18	100.95
10	No ana	lysis made						
11	No ana	lysis made						
12	No ana	lysis made						
13	40.80	11.30	5.70	24.98	...	...	18.00	100.78
14	33.94	13.16	3.64	24.84	...	...	19.04	94.62
15	40.16	12.98	12.58	18.52	3.81	3.50	9.28	100.83
16	34.34	14.08	15.48	16.60	4.26	4.30	10.80	99.86
17	No ana	lysis made						
18	36.80	12.48	5.52	25.04	...	...	21.50	101.34
19	35.82	10.64	14.06	27.25	...	...	11.10	98.87
20	38.40	8.83	15.57	26.43	...	...	10.50	99.73
21	35.68	14.53	2.15	24.65	...	...	21.63	98.64
22	38.20	21.89	5.13	26.30	...	...	7.43	98.95
23	35.36	19.25	14.57	20.50	...	...	11.23	100.91
24	35.68	13.99	9.11	22.30	...	...	18.20	99.28
25	37.02	16.77	14.91	22.40	...	...	8.37	99.47
26	33.96	10.57	7.45	33.00	0.15	1.98	9.57	96.68
27	33.80	14.66	6.62	31.10	...	...	12.08	98.26
28	No ana	lysis made						
29	34.66	11.72	13.08	21.89	0.60	3.44	13.86	99.25
30	34.96	15.91	15.90	24.80	...	...	9.12	100.69
A	39.00	18.64	15.16	23.10	...	...	3.80	99.70
B	59.90	17.79	8.11	10.10	...	...	3.70	99.60
C	29.98	22.89	2.23	28.40	...	...	14.05	97.55

A is sample of expanded vermiculite from Bee Tree plant (Swannanoa).
B is sample of kyanite matrix from contact zone at Cane Creek property.
C is sample of chlorite from Mincey mine (Ellijay).

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